Predicative representations of relations and links of the intellectual operational-technological control in complex dynamic systems

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Dmitry Alexandrovich Pospelov – the scientist, the author of the situational control and the mastermind of the artificial intelligence research, of blessed memory.

***Abstract*—The research belongs to the field of "intelligent control systems", where it is important to "learn", "understand", "remember", "evaluate the situation", "find a solution", "check the execution" and combines methods for solving intellectual problems, independently not solved by the human operator "in principle". The cognitive hybrid intellectual systems are proposed for computer simulation of cognitive formations and enhancing human intelligence in operational work. In respect of such systems we developed the language for the description of relations and links for predicative coding of verbal knowledge about resources, properties and actions of personnel, for coding of the grammar of identity substitution and the functional deformation of the cognitive image of the object state.**

***Keywords*—intelligent control systems, cognitive image, operational image, cognitive hybrid intellectual systems, language for describing relations and links, predictive coding**

I. Introduction

In the seminal work [1] is emphasized: "Thinking is primarily the establishment of relationships between objects. With the help of special thought mechanisms the environment, in which the subject lives and acts, is recreated in his head with the reflection of those signs and links that are found between objects. In contrast to the language of perception, in which, first of all, those properties of objects are fixed, which are manifested in influences on the senses, a special language of relations and links is characteristic of thinking. Through this specific language, a subject gets the opportunity for internal work with those objects and their properties that are not given in perception, which are outside the scope of his direct contacts". The first results of our researches on the semantics of relations in verbal-symbolic representations of knowledge of intelligent systems are reflected in [2]. Later they were developed in [3], [4] within the linguistic approach to hybridization and within the problem-structured methodology and technology of the functional hybrid intellectual systems (HyIS). In the paper we considered the development of the language describing relations and links (LDRL) for predictive coding of word and verbal knowledge about resources, properties and actions of the personnel, for coding the grammar of identical transformations and functional deformation of the cognitive image of the state of a control object.

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II. Predicative model of cognitive and operational image of the object of operational-technological control in complex dynamic systems

The key aspect of the operator's performance is remote control of the object which is out of sight of the controlling operator. Then the operator by the actions physically transforms the control object, without observing it directly. In such conditions the image of the control object (CO) acquires the specific meaning — representation "turning an absent object into a present in the mind" [5]. The control would be effective if the image reflects the important for the operator aspects of the CO and if the image is relevant to his operational actions. The cognitive image (CI) of the object of control as per D.A. Oshanin — the result of the cognitive reflection function, an instrument for completing the knowledge of the CO. This is the worldview and the "depository" of information about the control object. CI is redundant, entropic and continuously developing, enriching and reducing, internally restructuring. CI is an instrument of "inventory" of potentially useful properties of CO. A cognitive image is an open information system for flexible switching from one structure to another depending on changes in relevant parameters.

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The operational image of an object (OO) of control as per D.A. Oshanin – the image of the OC as a result of the regulatory function of reflection, which is formed by the human-operator (the subject of control) in the process of fulfilling the tasks of operational-technological control (OTC). Its a functional psychological system (model) that processes information about the sequential states of the object into appropriate action on him. The operator's reflections on the CO image and the changes (transformations) that the CO image undergoes under this are called the dynamics of the operational image according to D.A. Oshanin. The operational image is dynamic, changeable, fluid, contradictory and regulates the specific action in time and space. It is pragmatic, "subordinate" to the problem being solved and relevant to it, specific, suitable only for a specific task, concise, peculiarly limited, "distracted" from the CO features that are not currently used to solve the task.

The semantic of CI and OO is reflected by the language of the professional activity (LPA) of the human-operator. The traditional model of abstract knowledge of LPA is predicative model with "predicate–argument" as the base structure, which can be assigned the values "true" or "false" [6]. It had a success in linguistic due to the possibility of organizing calculations, and for many years predetermined the "linguistic turn" in the philosophy of knowledge [7]. In classical logic of Aristotel the subject was defined as the entity of statement. The subject (σ) can be associated either with a resource of the CO, or with the human-operator notion of it. The statement of resource is made in the form of a predicate (ρ), positive or negative statement. The structure of attributive statement is represented by the formula $\sigma - \rho$. A connective (the verb *is*) can be introduced into it as a component expressing the inherent or non-inherent character of the feature to the resource.

Afterwards, attributive logic was being displaced by the relational logic, defining the predicate not as a property of a resource (σ — ρ or σ *is* ρ), but as a relation between two (or three, etc.) resources (arguments). This was reflected in formulas of type $\rho\ (x, y)$, $\rho\ (x, y, z)$, where ρ symbolize monadic or dyadic predicate.

Predicate (lat. praedicatum, from praedicare – make known beforehand, declare) [8] – something which is affirmed or denied concerning an argument of a proposition; assert (something) about the subject of a sentence or an argument of proposition. Thus, predicate is the term of logic and linguistics, denoting the constitutive member of a statement. It is what one expresses (affirms or denies) about the subject. By the number of actants predicates are divided into monadic; dyadic; triadic; four-place, etc. At a syntactic level a predicate is a kernel structure with actants. A kernel is a verbal construction. Actants combine with a kernel by the system of relations. Nodes of this construction are names (noun, pronoun, numerals) in their attributive form. A syntax (formalized record) of a predicate for the atomic sentence is accepted in the following interpretation:

(ACTION) *to have as a subject* (SUBJECT), (ACTION) *to have as an object* (OBJECT1), (ACTION) *to exist* (OBJECT2), *to have a result* (OBJECT3), (OBJECT) *to have a mean* (OBJECT4), (ACTION) *to have a mean* (OBJECT5), *whence* (OBJECT6), (ACTION) *to where* (OBJECT7),

(ACTION) (*R0* (SUBJECT) *R1* (OBJECT1)*R2* (OBJECT2), *R3* (OBJECT3) *R4* (OBJECT4) *R4* (OBJECT5) *R5*(OBJECT 6) *R6* (OBJECT7)),

(XD) (R0 (XS) R1(XO1) R2 (XO2), R3 (XO3) R4 (XO4) R4 (XO5) R5(XO6) R6 (XO7)),

where ACTION, *XD* – the kernel of a predicate (predicator), in the general case, its a verb structure that may have additional attribute components; SUBJECT, *XS* – an object of the predicate, a material entity, an intangible object, "empty"; OBJECT1, *XO1*,. . . , OBJECT 7, *XO7* – actants, may be represented by special objects or in the form of concrete characteristics of the predicator, indicated by adverbs (*yesterday, today, there, here, etc.*); *R0* – the relation "*to be a subject*", *R1*,. . . , *R7* – relations of a predicate.

The size of the message decrease, it is coding by the replacement according to the qualified agreement names of ACTION, SUBJECT, OBJECT and relations by their code values, on which the quality and efficiency of using CI and processing OO in cognitive HyIS depends.

Such coding is named predicative RKX-coding. Codes of names of relations and concepts are formed by the rules in conformity with the next classification of relations: "resource-resource", "property-property", "action-action", "resource-property", "property-resource", "resource-action", "action-resource", "action-property", "property-action" and their formal-logical properties [9]

RKX -codes include not only features of the name (relation – *R* , concept *X*, their number in the dictionary), but also features of the formal-logical properties (symmetric, transitive, direct, reverse, etc.) and features of the membership to classes according to D.A. Pospelov (classifications, indicative, quantitative, comparisons, implementation, etc.) and to classes according to A.V.

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The formation of syntagmatic, situational relations occurs in a different way. This relationship is "to be time", "to be space", "to be a cause", "to be a consequence", etc. Situational relationships are common in LPA because they recreate spatio-temporal and causal relationships that explicitly or implicitly always present in operational messages. Language practice has developed forms for the implementation of these relations – syntagmas and syntagmatic chains.

A syntagma according to P.M. Kolychev [10] – binomial juxtaposition of any language elements in a linear sequence: VALUE *equal* 50, SUBSTATION SEVERNAYA *near* KALININGRAD, TRANSFORMATOR *is at* SUBSTATION. At the abstractive level a syntagma has the next form:

$$(OBJECT1)R(OBJECT2)or(XO1)R(XO2) \quad (1)$$

where OBJECT1, *XO1* – abstraction from VALUE, SUBSTATION SEVERNAYA, TRANSFORMATOR; OBJECT2, *XO2* – abstraction from 50, KALININGRAD, SUBSTATION; *R* – abstraction from *equal, near, is at* and suchlike.

A syntagma (1), a "tripod" as simple kernel construction according to D.A. Pospelov. It is the basic unit of the language of situation control. There is a relation *R* in the center of the construction. On the ends of the construction there are the left (*XO1*) and the right (*XO2*) poles – concepts (parentheses are used as delimiters). Relations *R* connect together the resources of the control object, which appear in them as certain roles, the semantics of which is determined by the type of relationship. Such relations *R* are called role-based.

III. Lexis of the language of relations and links of cognitive and operational images in a predicative model

The classification of concepts interprets the three philosophical categories of A.I. Uemov ("thing", "property" and "relation") in terms of "intelligent control systems for electrical networks and electrical installations" (the subject area).

Each concept in LDRL is denoted by $x^n \in X^n$, where n = 0 – a feature of a basic concept, $n \in \{1, 2, \dots\}$ – a feature of a derivative, complex concept. Let's represent a set of concepts of the LDRL as $X^0 = X^0_\alpha \bigcup X^0_\beta$, where X^0_α, X^0_β – the basis and the auxiliary subsets. The basis set is denoted by three categories: *resource, property and action*. In the LPA sentences, they are mainly expressed by nouns, adjectives, ordinal numbers and definitive adverbs. The auxiliary set of concepts is denoted by categories: *measure, value, characteristic, parameter, name, state, estimate, exotic*. To construct the classifier X^0, the corresponding definitions are adopted [3], which are one-to-one related to the following predicates: $\rho^1_1\left(x^0\right)$ - *to be a resource*, $\rho^1_2\left(x^0\right)$ - *to be a property*, $\rho^1_3\left(x^0\right)$ - *to be an action*, $\rho^1_4\left(x^0\right)$ - *to be a measure*, $\rho^1_5\left(x^0\right)$ - *to be a value*, $\rho^1_6\left(x^0\right)$ - *to be a character* (*characteristic property*), $\rho^1_7\left(x^0\right)$ - *to be a parameter* (*physical property*), $\rho^1_8\left(x^0\right)$ - *to be a name* (*name property*), $\rho^1_9\left(x^0\right)$ – *to be a state*, $\rho^1_{10}\left(x^0\right)$ - *to be an estimate*, $\rho^1_{11}\left(x^0\right)$ – *to be an exotic concepts*.

The introduced categories are defined through gender-specific differences, examples and relationships with parts of speech. This makes the class separation of X^0 understandable and outlines a certain formalism in the semantic decomposition of expressions of the LPA. Exotic concepts make the classification easily extensible by analysis of elements ${}^{11}X^0$ and introducing of new definitions and corresponding predicates.

If we set three of imposed above predicates over X^0

$$M_1 = < X^0, \rho^1_i\left(x^0\right) \mid i \in \overline{1;5}, i \in \{9, 10, 11\} >, \quad (2)$$

then we would get the separation of X^0 into eight subsets: ${}^1X^0$ – resources, ${}^2X^0$ – properties and ${}^3X^0$ – actions, ${}^4X^0$ – measures, ${}^5X^0$ – values, ${}^6X^0$ – states, ${}^7X^0$ – estimates и ${}^8X^0$ – exotic concepts. Meanwhile, there must be implemented the next: $X^0 = \bigcup_i {}^iX^0$, if $i \in \overline{1;8}$ and $\varnothing = \bigcup\left({}^iX^0 \bigcap {}^jX^0\right)$, if $i \neq j$ and $i, j \in \overline{1;8}$. Because of informality of the separation procedure of X^0 into subsets, two things can take place: ${}^ix^0_k \equiv^j x^0_m$ and ${}^ix^0_k, {}^jx^0_m \in {}^zX^0 | i = j = z$ – duplication of concepts, and also ${}^ix^0_k \equiv^j x^0_m$ and ${}^ix^0_k \in {}^iX^0, {}^jx^0_m \in {}^jX^0 | i \neq j$ – a disambiguation. Both of it can be detected formally, but if the first one is eliminated easily, the second demands the analysis by a subject.

If we set predicates $\rho^1_6\left(x^0\right)$, $\rho^1_7\left(x^0\right)$, $\rho^1_8\left(x^0\right)$ over ${}^2X^0$

$$M_2 = < {}^2X^0, \rho^1_i\left({}^2x^0\right) | i \in \overline{6;8} > \quad (3)$$

then we would get the separation of ${}^2X^0$ into three subsets: ${}^{21}X^0$ – parameters, ${}^{22}X^0$ – characteristics, ${}^{23}X^0$ – names. There must be implemented: ${}^2X^0 = \bigcup_i {}^{21i}X^0$ if $i \in \overline{1;3}$ and $\varnothing = \bigcup\left({}^{21i}X^0 \bigcap {}^{21j}X^0\right)$, if $i \neq j$ and $i, j \in \overline{1;3}$. If $x^0_k \in X^0$ and $\forall \rho^1_i\left(x^0_k\right) | i \in \overline{1;10}$ = false, then $x^0_k \in {}^8X^0$

The second group of LDRL lexical items includes relations of the next classes (by D.A. Pospelov): of definition (DEF15 – here and below this is the code of the class of a relation "definition"), of comprasion (DEF16), spatial (DEF17), temporal (DEF18), of inclusion (DEF19), of causality (DEF20) and of preference (DEF21). In LPA relations of resources is denoted by nouns (*part, identity, equality, object, subject, means, etc.*) and related to the them adjectives (*identical, equal, etc.*), verbs (*have, be, exist, characterize, etc.*), prepositions, unions or by their combination (*be over, be behind, be before, etc*).

Each relation (link) in LDRL is denoted by $r^0 \in R^0$ or $r^\pi \in R^\pi$ depending on the denoting in the LPA by a word or an expression. Let's relate predicates to definitions DEF15–DEF21: $\rho^1_{12}\left(r^0\right)$ – *to be a relation of definintion*, $\rho^1_{13}\left(r^0\right)$ – *to be a relation of comprasion*, $\rho^1_{14}\left(r^0\right)$ – *to* *be a spatial relation*, $\rho_{15}^{1}\left(r^{0}\right)$ *– to be a temporal relation*, $\rho_{16}^{1}\left(r^{0}\right)$ *– to be a relation of inclusion*, $\rho_{17}^{1}\left(r^{0}\right)$ *– to be a relation of causality*, $\rho_{18}^{1}\left(r^{0}\right)$ *– to be a relation of preference.*

Then, having denoted imposed predicates over R^0

$$M_3 =< R^0,\ \rho_i^1\left(r^0\right) | i \in \overline{12;18} > \tag{4}$$

we would get the separation of R^0 into seven subsets of relations: ${}^1R^0$ – of definition, ${}^2R^0$ – of comprasion, ${}^3R^0$ – spatial, ${}^4R^0$ – temporal, ${}^5R^0$ – of inclusion, ${}^6R^0$ – of causality, ${}^7R^0$ – of preference. Meanwhile, there must be implemented: $R^0 = \bigcup_i {}^iR^0$, if $i \in\ \overline{1;7}$ and, because r_1^0 *– to be* $\in\ {}^2R^0$, ${}^3R^0$, ${}^4R^0$, to be r_2^0 *– to have* $\in\ {}^1R^0$, ${}^5R^0$, ${}^6R^0$, ${}^7R^0$, then generally $\varnothing = \bigcup\left({}^iR^0 \bigcap {}^jR^0\right)$, if $i \neq j$ and $i, j \in\ \overline{1;7}$.

The model M_3 follows the classification of D.A. Pospelov and gives the opportunity to allocate in the LPA relations and links of seven classes. It also allows to fill the corresponding dictionaries, but it doesn't denote the structure of signs of the LDRL.

Let's build the complete graph G_1

$$G_1 = \Big({}^1X^0, {}^2X^0, {}^3X^0; \\ R_{11}, R_{22}, R_{33}, R_{12}, R_{21}, R_{13}, R_{31}, R_{23}, R_{32}\Big), \tag{5}$$

where $R_{11} = \{R_{11}^0, R_{11}^\pi\}$, $R_{22} = \{R_{22}^0, R_{22}^\pi\}$, $\ldots$, $R_{32} = \{R_{32}^0, R_{32}^\pi\}$. Let us define relations R_{ij}^0, without going beyond the classification of concepts M_1 and M_2, the classification of relations M_3. Meanwhile, $\frac{1}{R}$ – inverse *R* – this is such relation in X^0, that for every ${}^iX^0$ and ${}^jX^0$ from X^0 the settlement ${}^iX^0\ \frac{1}{R}\ {}^jX^0$ equivalents to ${}^jX^0\ R\ {}^iX^0$. R30(R_{11}^0 – the relation between concepts ${}^1x^0 \in^1 X^0$, including ${}^1R_{11}^0$, ${}^3R_{11}^0$, ${}^5R_{11}^0$) . R31(R_{22}^0 – ${}^2x^0 \in {}^2X^0$; ${}^1R_{22}^0$, ${}^3R_{22}^0$, ${}^5R_{22}^0$). R32(R_{33}^0 – ${}^3x^0 \in {}^3X^0$; ${}^1R_{33}^0$, ${}^4R_{33}^0$, ${}^5R_{33}^0$, ${}^6R_{33}^0$). R33(${}^1X^0\ R_{12}^0\,{}^2X^0 = \{{}^1X^0\ {}^1R_{12}^0\,{}^2X^0\}$). R34(${}^2X^0 R_{21}^0\,{}^1X^0 = \{{}^2X^{01}R_{21}^0\,{}^1X^0 | {}^1R_{21}^0 = \frac{1}{{}^1R_{12}^0}\}$). R35(${}^1X^0 R_{13}^0\,{}^3X^0 = \{{}^1X^{01}R_{13}^0\,{}^3X^0, {}^1X^{06}R_{13}^0\,{}^3X^0\}$). R36(${}^3X^0\ R_{13}^0\,{}^1X^0 = \{{}^3X^{01}R_{31}^0\,{}^1X^0, {}^3X^{06}R_{31}^0\,{}^1X^0 | {}^6R_{31}^0 = \frac{1}{{}^6R_{13}^0}\}$). R37(${}^3X^0\ R_{32}^0\,{}^2X^0 = \{{}^3X^{01}R_{32}^0\,{}^2X^0\}$). R38(${}^2X^0\ R_{23}^0\,{}^3X^0 = \{{}^2X^{01}R_{23}^0\,{}^3X^0 | {}^1R_{23}^0 = \frac{1}{{}^1R_{32}^0}\}$).

Consider the graph G_2, whose vertexes are indicated by the sets ${}^2X^0$, ${}^4X^0$, ${}^5X^0$ – are values. Then edges of the graph define the system of relations, from which we allocates the next: R_{24} – *property-measure*, R_{25} – *property-value*, R_{45} – *measure-value*:

$$G_2 = \left({}^2X^0, {}^4X^0, {}^5X^0, R_{44}, R_{55}, R_{25}, R_{45}\right), \tag{6}$$

where $R_{24} = \{R_{24}^0, R_{24}^\pi\}$, $R_{25} = \{R_{25}^0, R_{25}^\pi\}$, $\ldots$, $R_{45} = \{R_{45}^0, R_{45}^\pi\}$. The last relations that doesn't contradict the next: R_{44} – *measure–measure*, for example, a km is more than a m, a kV is more than a V; R_{55} - *value–value*, for example, 10 > 2, high voltage is more than low voltage, we'll consider, denoting R_{22}. R39(${}^2X^0\ R_{24}^0\,{}^4X^0 = \{{}^2X^0\ {}^1R_{24}^0\,{}^4X^0\}$). R40(${}^2X^0\ R_{25}^0\,{}^5X^0 = \{{}^2X^0\ {}^1R_{25}^0\,{}^5X^0\}$). R41(${}^4X^0\ R_{45}^0\,{}^5X^0 = \{{}^2X^0\ {}^1R_{24}^0\,{}^4X^0\}$).

Consider the graph G_3, whose vertexes are indicated by the sets ${}^1X^0$, ${}^3X^0$, ${}^6X^0$, ${}^7X^0$.

$$G_3 = \left({}^1X^0, {}^3X^0, {}^6X^0, {}^7X^0, R_{66}, R_{77}, R_{16}, R_{37}\right), \tag{7}$$

where $R_{66} = \{R_{66}^0, R_{66}^\pi\}$, $R_{77} = \{R_{77}^0, R_{77}^\pi\}$, $R_{16} = \{R_{16}^0, R_{16}^\pi\}$, $R_{37} = \{R_{37}^0, R_{37}^\pi\}$. Then edges define the system of relations, from which we allocates: R_{66} – *state-state*, R_{77} – *estimate-estimate*, R_{16} – *resource-state*, R_{37} – *action-estimate*. R42(${}^1X^0\ R_{16}^0\,{}^6X^0 = \{{}^1X^0\ {}^1R_{16}^0\,{}^6X^0\}$). R43(${}^3X^0\ R_{37}^0\,{}^7X^0 = \{{}^3X^{01}R_{37}^0\,{}^7X^0\}$). R44(${}^6X^0 R_{66}^0\,{}^6X^0 = \{{}^6X^0\ {}^4R_{66}^0\,{}^6X^0, {}^6X^0\ {}^6R_{66}^0\,{}^6X^0\}$). R45(${}^7X^0\ R_{77}^0\,{}^7X^0 = \{{}^7X^0\ {}^7R_{77}^0\,{}^7X^0, {}^7X^0\ {}^2R_{77}^0\,{}^7X^0\}$).

We establish a one-to-one correspondence between definitions R30 – R45 and predicates: $\rho_{20}^1\left(r^0\right)$ *– to be* R_{11}^0 , $\rho_{21}^1\left(r^0\right)$ *– to be* R_{22}^0 , $\rho_{22}^1\left(r^0\right)$ *– to be* R_{33}^0 , $\rho_{23}^1\left(r^0\right)$ *– to be* R_{12}^0 , $\rho_{24}^1\left(r^0\right)$ *– to be* R_{21}^0 , $\rho_{25}^1\left(r^0\right)$ *– to be* R_{13}^0 , $\rho_{26}^1\left(r^0\right)$ *– to be* R_{31}^0 , $\rho_{27}^1\left(r^0\right)$ *– to be* R_{23}^0 , $\rho_{28}^1\left(r^0\right)$ *– to be* R_{32}^0 , $\rho_{29}^1\left(r^0\right)$ *– to be* R_{24}^0 , $\rho_{30}^1\left(r^0\right)$ *– to be* R_{25}^0 , $\rho_{31}^1\left(r^0\right)$ *– to be* R_{45}^0 , $\rho_{32}^1\left(r^0\right)$ *– to be* R_{16}^0 , $\rho_{33}^1\left(r^0\right)$ *– to be* R_{37}^0, $\rho_{34}^1\left(r^0\right)$ *– to be* R_{66}^0, $\rho_{35}^1\left(r^0\right)$ *– to be* R_{77}^0 . Then having devoted imposed predicates over R^0

$$M_4 =< R^0, \rho_i^1\left(r^0\right) | i \in \overline{20;31} > \tag{8}$$

we would get the separation of R^0 into subsets R_{11}^0, R_{22}^0, $\ldots$, R_{23}^0, R_{24}^0, R_{25}^0, R_{45}^0, R_{16}^0, R_{37}^0, R_{66}^0, R_{77}^0. Meanwhile, there must be implemented the next: $R^0 = \bigcup_{ij} R_{ij}^0$, if $i \in \overline{1;7}$, $j \in \overline{1;7}$, and generally $\varnothing = \bigcup\left(R_{ij}^0 \bigcap R_{km}^0\right)$, if $i \neq k, j \neq m$ and $i, k \in \overline{1;7}$, $j, m \in \overline{1;7}$. For example: R_{11}^0 = {*to be, in, near, a part, to have a composition*}, R_{22}^0 = {*to be, more, less, equal*}, R_{33}^0 = {*to be simultaneously, earlier*}, R_{31}^0 = {*to have, a subject, an object, a means*}, R_{13}^0 = {*to be, condition, an object, a means, a place*}, R_{32}^0 = {*to have, a duration, a result*}. Relations from the classes R_{12}^0, R_{21}^0, R_{23}^0, R_{24}^0, R_{25}^0, R_{45}^0, R_{16}^0, R_{37}^0 include verbs *to be*, *to have*, and devoted in M_1 M_2 concepts *parameter*, *characteristic, name*, *measure, etc.*

After definition of the base relations R_{ij}^0 we'll consider the auxiliary ones R_{ij}^π. We define the language of the first level as $L_1(X^0, R_{ij}^0, P^1)$ = $\{r_{ij_l}^\pi\}$ – the set of auxiliary relations $\{\ r_{11_1}^\pi, r_{11_2}^\pi, \ldots, r_{11_\delta}^\pi, r_{22_1}^\pi, r_{22_2}^\pi, \ldots, r_{22_\varepsilon}^\pi, \ldots, r_{45_1}^\pi, r_{45_2}^\pi, \ldots, r_{45_\varrho}^\pi\ \}$ = R_{ij}^π derived from target relationships r_1^0 *– to have* and r_2^0 *– to be* by the rules $P^1 = \{p_1^1,\ p_2^1\}$.

Rule p_1^1, which we devote inductively. It's applied to the classes R_{11}^0, R_{22}^0, R_{33}^0*: 1) If* r_k^0– the target relationship and $r_{\mathrm{ij}_m}^\pi \in R_{\mathrm{ij}}^0 | i = j = \{1,2,3\}$, *then* $r_{\mathrm{ij}_l}^\pi = r_k^0 r_{\mathrm{ij}_m}^0 | k \in \overline{1;2}$ – the *auxiliary* relation in R_{ij}^π; 2) If $r_{\mathrm{ij}_l}^\pi$– the *auxiliary* relation, then $r_{\mathrm{ij}_l}^\pi r_{\mathrm{ij}_m}^0$ is also the *auxiliary* relation; 3) There are no others *auxiliary* relations in R_{ij}^π .

Rule p_2^1, which is applied to the classes R_{12}^0, R_{21}^0, R_{23}^0, R_{32}^0, R_{24}^0, R_{25}^0, R_{45}^0, R_{16}^0, R_{37}^0, ${}^{211}X^0, {}^{212}X^0$: 1) *If* r_k^0– the target relationship and $r_{\mathrm{ij}_m}^0 \in R_{\mathrm{ij}}^0 | i = \{1,2,4\}, j \in \overline{1;5}, i \neq j$, ${}^{21n}x^0 \in {}^{21n}X^0 | n = \{1,2\}$, then $r_{\mathrm{ij}_l}^{\pi} = r_k^0 r_{\mathrm{ij}_m}^0 | k \in \{1,2\}$ or $r_{\mathrm{ij}_l}^{\pi} = r_k^0\ {}^{21n}x^0$ – the auxiliary relation in R_{ij}^{π}; 2) There are no others auxiliary relations in R_{ij}^{π} .

IV. RKX – coding of the semantics of relations and links of cognitive and operational images within the predicative model of the professional activity language

Thus, basis and auxiliary relations are defined (3)–(7) over ${}^1X^0$, ${}^2X^0$, $\ldots$, ${}^7X^0$ and we can build the graph $G = G_1 \bigcup G_2 \bigcup G_3$. Models M_1 – M_4 (1)–(4) define of components of G, which define the structure of strings of the LDRL. To show this we'll expand the system by the next model:

$$M_5 = < \widehat{X},\ \{\rho_{i,j}^1({}^vx^0)\},\ \{\rho_{i,j}^2({}^dx^0, {}^{\varepsilon}x^0)\}, \{\rho_{i,j}^3({}^gx^0, {}^qx^0, {}^hx^0)\},\ |\ i = \{12, \ldots, 18\}, j\ = \{1,2,3,20,\ldots,31\} >,$$

where $\rho_{i,j}^1\left({}^vx^0\right) = \begin{cases} t, \text{if } r_{\mathrm{ij}_l}^{\pi}\,{}^vx^0, \\ f, \text{otherwise} \end{cases}$,

$\rho_{i,j}^2({}^dx^0, {}^{\varepsilon}x^0) = \begin{cases} t, \text{if } {}^dx^0 r_{\mathrm{ij}_m}^{\pi}\,{}^{\varepsilon}x^0, \\ f, \text{otherwise} \end{cases}$,

$\rho_{i,j}^3\left({}^gx^0, {}^qx^0, {}^hx^0\right) = \begin{cases} t, \text{if } {}^gx^0\ r_{\mathrm{ij}_k}^{\pi}\ {}^qx^0\ \ r_{\mathrm{ij}_k}^{\pi}\,{}^hx^0, \\ f, \text{thewise} \end{cases}$,

$\widehat{X} = X^0 \bigcup \varnothing$; $r_{\mathrm{ij}_l}^{\pi},\ r_{\mathrm{ij}_m}^{\pi},\ r_{\mathrm{ij}_k}^{\pi} \in R_{\mathrm{ij}}^{\pi}$; ${}^fx^0 \in {}^fX^0 | f = v,\ d,\ \varepsilon,\ g,\ q,\ h.$

If to devote concatenation operator " $\circ$ " over the signature $P_5 = \left\{ \left\{\rho_{i,j}^1\left({}^vx^0\right)\right\}, \left\{\rho_{i,j}^2\left({}^dx^0, {}^{\varepsilon}x^0\right)\right\}, \{\rho_{i,j}^3({}^gx^0, {}^qx^0, {}^hx^0)\} \right\}$, then the following five axioms are possible. Structures of strings denoting resources, properties, actions and links between resources and actions are defined only by expressions A1 – A5 correspondingly:

A1. $\rho_{11,1}^1\left({}^1x_a^0\right) \circ \rho_{11,20}^2\left({}^1x_a^0, {}^2x_b^0\right) \circ \rho_{11,22}^2\left({}^1x_a^0, {}^3x_c^0\right) \circ \rho_{15,17}^2\left({}^1x_a^0, {}^1x_d^0\right)$,

A2. $\rho_{11,2}^1\left({}^2x_a^0\right) \circ \rho_{11,21}^2\left({}^2x_a^0, {}^1x_b^0\right) \circ \rho_{11,26}^2\left({}^2x_a^0, {}^3x_c^0\right) \circ \rho_{11,26}^2\left({}^2x_a^0, {}^4x_d^0\right) \circ \rho_{11,27}^2\left({}^2x_a^0, {}^5x_c^0\right) \circ \rho_{15,18}^2\left({}^2x_a^0, {}^2x_t^0\right)$,

A3. $\rho_{11,3}^1\left({}^3x_a^0\right) \circ \rho_{11,25}^2\left({}^3x_a^0, {}^2x_b^0\right) \circ \rho_{11,23}^2\left({}^3x_a^0, {}^1x_c^0\right) \circ \rho_{15,19}^2\left({}^3x_a^0, {}^3x_d^0\right)$,

A4. $\rho_{13,1}^2\left({}^1x_a^0, {}^1x_b^0\right) \circ \rho_{13,1}^3\left({}^1x_a^0, {}^1x_b^0, {}^2x_c^0\right)$,

A5. $\rho_{16,3}^2\left({}^3x_a^0, {}^3x_b^0\right) \circ \rho_{14,3}^2\left({}^3x_a^0, {}^3x_b^0\right) \circ \rho_{14,3}^3\left({}^3x_a^0, {}^3x_b^0, {}^2x_c^0\right)$.

A1–A3 are clear. In A4 – A5 dyadic predicates determine qualitative spatial relations, and triadic predicates determine quantitative spatial and temporal. Considered system M_1– M_5 is the semantic, predicative model of expressions of the LPA. From one side, it allows to analyze expressions (M_1– M_4), and, from the other side, it allows to synthesize strings of the LDRL.

Concepts ${}^1x^0$, ${}^3x^0$ devote classes of resources and actions in LDRL whithout taking into account any distinctive features of the latter and correspond, basically, to the words of the LPA. Modelling of resources and actions consists in building of expressions-strings, devoting elements of classes and subclasses of resources and actions, related to phrase of the LPA and consisting of concepts ${}^1x^0$, ${}^2x^0, \ldots$, ${}^7x^0$ and auxiliary relations $r_{\mathrm{ij}_l}^{\pi}$. Denotation is not only substitution of reality with a sign in LDRL, but also an indication when a resource, action or their links can be associated with any string. Denotation of simple and complex resources, properties and actions in LDRL is implemented at the second and the third levels, correspondingly. Consider the language of the second level as

$$L_2\left(X^0, {}^1R_{\mathrm{ij}}^{\pi},\ (,)\ ,\ \mathcal{P}^2\right) = \{{}^ix_k\}$$

a set of auxiliary concepts $\{{}^1x_1, {}^1x_2, \ldots\ ,\ {}^1x_{\eta}, {}^2x_1, {}^2x_2, \ldots\ ,\ {}^2x_{\varphi}, {}^3x_1, {}^3x_2, \ldots\ ,\ {}^3x_{\psi}\}$ = X, obtained from $X^0, {}^1R_{\mathrm{ij}}^{\pi}, (,)$ within rules $\mathcal{P}^2$ and devoting simple resources, properties and actions. Consideration of rules $\mathcal{P}^2 = \{p_1^2, p_2^2, p_3^2\}$, interpreting correspondingly axioms A1–A3, more convenient to start from p_2^2.

Denotations: BF – a basis feature, AF – an additional feature, AC – an auxiliary concept.

Rule p_2^2. 1) If $r_{22_l}^{\pi} \in {}^1R_{22}^{\pi}$ and ${}^2x_m^0 \in {}^2X^0$, then $r_{22_l}^{\pi}\,{}^2x_m^0$ – CO in ${}^2X$; 2) If $r_{\mathrm{ij}_l}^{\pi} \in {}^1R_{21}^{\pi}$,${}^1R_{23}^{\pi}$,${}^1R_{24}^{\pi}$,${}^1R_{25}^{\pi}$ and *i* = 2, *j* = {1,3,4,5}, ${}^jA = {}^jx_k^0$, ${}^jA = {}^jA\ {}^jx_n^0$, then $({}^2xk^0 r_{\mathrm{ij}_l}^{\pi}\,{}^jA)$ or $r_{\mathrm{ij}_l}^{\pi}\left({}^jA\right)$ is AF in ${}^2X$; 3) If ${}^2B$ is BF and ${}^2C$ is AF, then ${}^2B\,{}^2C$ is AC in ${}^2X$; 4) If ${}^2C$ is BF and ${}^2D$ is AF, then ${}^2C\,{}^2D$ is AC in ${}^2X$; 5) There are no others AC in ${}^2X$.

Rule p_1^2. 1) If $r_{11_l}^{\pi} \in {}^1R_{11}^{\pi}$ and ${}^1x_m^0 \in {}^1X^0$, then $r_{11_l}^{\pi}\ {}^1x_m^0$ is BF in ${}^1X$; 2) If $r_{\mathrm{ij}_f}^{\pi} \in {}^1R_{12}^{\pi}$,${}^1R_{13}^{\pi}$ and *i* = 1, *j* = {2,3}, ${}^jA = {}^jx_{\pi}^0, {}^jA = {}^jx_k$, ${}^jA = {}^jA\ {}^jx_a^0, {}^jA = {}^jA\ {}^jx_b$, then $({}^1xk^0 r_{\mathrm{ij}_f}^{\pi}\,{}^jA)$ or $r_{\mathrm{ij}_f}^{\pi}\left({}^jA\right)$ is AF in ${}^1X$; If ${}^1B$ is BF and ${}^1C$ is AF, then ${}^1B\,{}^1C$ is AC in ${}^1X$; 4) If ${}^jD$ is AC in ${}^2X$ or ${}^3X$, then $\left({}^1x_m^0 r_{\mathrm{ij}_f}^{\pi}\left({}^jD\right)\right)$ is AF in ${}^1X$; 5) If ${}^1D$ is AC and ${}^1C$ is AF, then ${}^1D\,{}^1C$ is AC in ${}^1X$; 6) There are no others AC in ${}^1X$.

Rule p_3^2. 1) If $r_{33_l}^{\pi} \in {}^1R_{33}^{\pi}$ and ${}^3x_m^0 \in {}^3X^0$, then $r_{33_l}^{\pi}\ {}^3x_m^0$ is BF in ${}^3X$;
2) If $r_{\mathrm{ij}_f}^{\pi} \in {}^1R_{31}^{\pi}$,${}^1R_{32}^{\pi}$ and *i* = 3, *j* = {1,2}, ${}^jA = {}^jx_n^0, {}^jA = {}^jx_k$, ${}^jA = {}^jA\ {}^jx_a^0, {}^jA = {}^jA\ {}^jx_b$, then

$({}^3x_m^0 r_{\mathrm{ij}_f}^{\pi}\, {}^jA)$ or $r_{\mathrm{ij}_f}^{\pi}({}^jA)$ is AF in ${}^3X$; 3) $If\ {}^3B$ is BF and ${}^3C\ is\ AF,\ then\ {}^3B^3C$ is AC in L_2; 4) If ${}^jD$ is AC in ${}^1X$ or${}^2X\ ,then\ \left({}^3x_m^0 r_{\mathrm{ij}_f}^{\pi}\left({}^jD\right)\right)$ is AF in ${}^3X$; 5) If ${}^3D$ is AC and ${}^3C$ is AF, then ${}^3D^3C$ is AC in ${}^3X$; 6) There are no others AC in ${}^3X$.

Finally, we can define the auxiliary concept of the L_2. It is AC in ${}^1X$ or AC in ${}^2X$ or AC in ${}^3X$. There are no others AC in L_2.

From the definition of L_2 and rules $\mathcal{P}^2$ we can see, that an auxiliary concept, from one side, is a symbol ${}^1x_k$ and from the other side, it is a string of features. If one establishes a one-to-one correspondence ${}^1x_k$=${}^jD_k$ between ${}^1x_1, {}^1x_2, \dots\ ,\ {}^1x_\eta$, ${}^2x_1, {}^2x_2, \dots\ ,\ {}^2x_\varphi, {}^3x_1, {}^3x_2, \dots\ ,\ {}^3x_\psi$ and strings ${}^jD_k|k = \{1, 2, \dots, \eta, \dots, \varphi, \dots, \psi\ \}$, then ${}^1x_k$ is the defined concept and ${}^jD_k$ is its definition. Such a record, when the derived concept is represented in the unity of the definable and the definition is used in identical transformations.

Consider the language of the third level as

$$L_3\left(X^0, X, {}^5R_{\mathrm{ij}}^{\pi},\ (,)\ ,\ \mathcal{P}^3\right) = \{{}^ix_k^n\}$$

a set of AC $\{{}^1x_1^n, {}^1x_2^n, \dots\ ,\ {}^1x_\eta^n, {}^2x_1^n, {}^2x_2^n, \dots\ ,\ {}^2x_\varphi^n, {}^3x_1^n, {}^3x_2^n, \dots\ ,\ {}^3x_\psi^n\} = X^n$, obtained from $X^0, X, {}^5R_{\mathrm{ij}}^{\pi},\ (,)$ within the rule $p_1^3 \in \mathcal{P}^3$, common for resources, properties and actions: 1) If $r_{\mathrm{ij}_l}^{\pi} \in {}^5R_{\mathrm{ij}}^{\pi}$ and $i = j = \{1{,}3\}$, ${}^iA = {}^ix_f^0$, ${}^iA = {}^ix_k$, ${}^iA = {}^iA\ {}^jx_a^0$, ${}^iA = {}^iA\ {}^jx_b^0$, then $r_{\mathrm{ij}_l}^{\pi}\left({}^iA\right)$ is a feature in ${}^iX^n$ (generally can be ${}^iA = \varnothing$); 2) If ${}^iC$ is a feature in ${}^iX^n$ and ${}^iD$ is AF in ${}^iX^n$, $then\ {}^iD^iC$ is AC in ${}^iX^n$; 3) There are no others AC in ${}^iX^n$.

Essentially, the rule p_1^3 of the language L_3 sequences auxiliary concepts of L_2 concerning the relation of inclusion (to have in composition or to be a part of) and forms a hierarchical structure. Thus, if ${}^1x_k^n$ are concrete, i.e. each of them responds to the only one resource, then ${}^3x_k^n$ is an abstraction, devoting the plan of actions and defining its properties and a list of features of resources involved for realization. If this list contain a name property, then the plan comes true. This leads to the establishing of relations $r_{\mathrm{ij}_l}^{\pi} \in {}^3R_{\mathrm{ij}}^{\pi}$ over resources and it also forms the situation in CO.

Modelling of spatial, productive structure, P- and O-situations is performed at the fourth level of LDRL. Consider the language of the fourth level as

$$L_4\left(X^0, X^n, \{{}^fR_{\mathrm{ij}}^{\pi}\},\ (,)\ ,\ \mathcal{P}^4\right) = \{{}^i\pi_k\}$$

A set of AC $\{{}^1\pi_1, {}^1\pi_2, \dots\ ,\ {}^1\pi_\lambda, {}^3\pi_1, {}^3\pi_2, \dots\ ,\ {}^3\pi_\nu\} = \Pi$, obtaining from $X^0, X^n, {}^3R_{\mathrm{ij}}^{\pi},\ {}^4R_{\mathrm{ij}}^{\pi},\ {}^6R_{\mathrm{ij}}^{\pi},\ (,)$ within the rule $p_1^4 \in \mathcal{P}^4$: 1) If $r_{\mathrm{ij}_l}^{\pi} \in {}^3R_{11}^{\pi}$, ${}^1D_a$ and ${}^1D_m$ are AC in ${}^1X^n$, then $({}^1D_a\ r_{11_l}^{\pi}\ ({}^1D_m))$ is AC in ${}^1\Pi \subset \Pi$; 2) If $r_{33_l}^{\pi} \in {}^4R_{33}^{\pi}$, ${}^6R_{33}^{\pi}$, ${}^3D_a$ and ${}^3D_m$ are AC in ${}^3X^n$, then $({}^3D_a\ r_{33_l}^{\pi}\ ({}^3D_m))$ is AC in ${}^3\Pi \subset \Pi$; 3) If ${}^i\pi_k$ and${}^i\pi_m$ is AC in ${}^i\Pi$, then $\pi_k\pi_m$ is AC in ${}^i\Pi$; 4) If $r_{11_l}^{\pi} \in {}^3R_{11}^{\pi}$, $r_{33_l}^{\pi} \in {}^4R_{33}^{\pi}$, ${}^6R_{33}^{\pi}$, ${}^3D_k$ and ${}^3D_m$ are AC in ${}^1X^n, {}^3X^n$, then $r_{11_l}^{\pi}\ {}^1D_k$ and $r_{33_l}^{\pi}\ {}^3D_m$ are features in ${}^1\Pi$, ${}^3\Pi$4; 5) If ${}^iA$ and ${}^iB$ are features, then ${}^iA^iB$ is also a feature in ${}^i\Pi$; 6) If ${}^iD_b$ is AC in ${}^iX^n$ and ${}^iA$ is a feature in ${}^i\Pi$, then $({}^iD_b\ \ ({}^iA))$ is AC in ${}^i\Pi$; 7) There are no others AC in Π.

Obvious that ${}^1\Pi$ can be described as spatial structure of CO ${}^1\Pi_C \subset^1 \Pi$. The current P-situation ${}^1\Pi_P \subset^1 \Pi$ similarly in ${}^3\Pi$ productive structure corresponds to ${}^3\Pi_C \subset^3 \Pi$ and O-situations to ${}^3\Pi_O \subset^3 \Pi$.

The formalism of the fifth level language allows to define the concept of a "cognitive image of the state of the control object". Consider the fifth level of LDRL as

$$L_5\left(\diamond,\ \mathcal{P}^5\right) = \{s_k\}$$

a set of AC – CI of states $\{s_1, s_2, \dots, s_\omega\}$ = S, formally deduced within the rule $p_1^5 \in \mathcal{P}^5$. Before giving the inductive definition of CI of a state, let's consider the substitution rule: if ${}^1x_m$=${}^1D_m$, ${}^3x_l$=${}^3D_l$ are correspondingly auxiliary concepts in ${}^1X^n$, ${}^3X^n$ and ${}^1x_f^0 \in {}^1D_m$, ${}^3D_l$, then the changing of ${}^1x_f^0$ in ${}^3\ D_l$ to ${}^1x_m$ or${}^1D_m$ is called substitution. After substitution the plan of actions ${}^3x_l$=${}^3D_l$ becomes true ${}^3\widehat{x}_l = {}^3\ \widehat{D}_l$.

Rule p_1^5 : *1) If* ${}^1\Pi_P \subset^1 \Pi$, ${}^3\Pi_O \subset^3 \Pi$ and $\{{}^1x_P = {}^1D_P\}$, $\{{}^3x_O = {}^3D_O\}$ are subsets of *auxiliary concepts* in ${}^1X^n$ and ${}^3X^n$, correspondingly, and ${}^{212}x^n = {}^{212}D|(r_{22_3}^{\pi}\, {}^{212}x_\mu^0\ r_{25_1}^{\pi}({}^5x_\omega^0)) \in {}^{212}D$, ${}^{212}x_\mu^0$ - *mode*, ${}^5x_\omega^0 \in$\{*normal*, *emergency*\} are AC in ${}^{212}X^0$, then ${}^3\widehat{\Pi}_O{}^1\Pi_P{}^{212}x_\mu^n$ (where $\{{}^3\widehat{x}_O = {}^3\ \widehat{D}_O\}$ is obtained as a result of substitution) is AC in *S*; 2) There are no others AC in *S*.

Consider the example of the expression $s \in S$. Suppose that at time *t* two actions are simultaneously performed
${}^3x_1^1 = r_{33_1}^{\pi}\, {}^3x_1^0 r_{31_1}^{\pi}\left({}^1x_1^0\right) r_{31_2}^{\pi}\left({}^1x_2^0\right) r_{31_3}^{\pi}\left({}^2x_3^0\right)$,
${}^3x_2^1 = r_{33_1}^{\pi}\, {}^3x_2^0 r_{31_1}^{\pi}\left({}^1x_4^0\right) r_{31_2}^{\pi}\left({}^1x_5^0\right)$, then ${}^3\pi_O = \left({}^3x_1^1\ r_{33_2}^{\pi}\, {}^3x_2^1\right)$.

If there were involved resources for realization

$${}^1x_1^1 = r_{11_1}^{\pi}\, {}^1x_1^0 r_{12_1}^{\pi}(r_{22_1}^{\pi}\, {}^{21^3}x_1^0 r_{25_1}^{\pi}({}^5x_1^0))$$
$$r_{12_1}^{\pi}(r_{22_2}^{\pi}\, {}^{21^1}x_1^0 r_{24_1}^{\pi}\left({}^4x_1^0\right) r_{25_1}^{\pi}({}^5x_2^0)),$$

$${}^1x_2^1 = r_{11_1}^{\pi}\, {}^1x_2^0 r_{12_1}^{\pi}(r_{22_1}^{\pi}\, {}^{21^3}x_1^0 r_{25_1}^{\pi}({}^5x_3^0))$$
$$r_{12_1}^{\pi}(r_{22_2}^{\pi}\, {}^{21^1}x_1^0 r_{24_1}^{\pi}\left({}^4x_1^0\right) r_{25_1}^{\pi}({}^5x_4^0)),$$

$$
\begin{aligned}
{}^1x_3^1 = {} & r^\pi_{11_1}\,{}^1x_3^0 r^\pi_{12_1}(r^\pi_{22_1}\,21^3\,x_1^0 r^\pi_{25_1}({}^5x_5^0)) \\
& r^\pi_{12_1}(r^\pi_{22_3}\,21^2\,x_1^0 r^\pi_{25_1}({}^5x_6^0)),
\end{aligned}
$$

$$
\begin{aligned}
{}^1x_4^1 = {} & r^\pi_{11_1}\,{}^1x_4^0 r^\pi_{12_1}(r^\pi_{22_1}\,21^3\,x_1^0 r^\pi_{25_1}({}^5x_7^0)) \\
& r^\pi_{12_1}(r^\pi_{22_3}\,21^2\,x_2^0 r^\pi_{25_1}({}^5x_8^0)),
\end{aligned}
$$

$$
\begin{aligned}
{}^1x_5^1 = {} & r^\pi_{11_1}\,{}^1x_4^0 r^\pi_{12_1}(r^\pi_{22_1}\,{}^{213}x_2^0 r^\pi_{25_1}({}^5x_9^0)) \\
& r^\pi_{12_1}(r^\pi_{22_3}\,{}^{212}x_3^0 r^\pi_{25_1}({}^5x_{10}^0)),
\end{aligned}
$$

then as a result of substitution we'll have ${}^3\widehat{x}_1^1 = r^\pi_{33_1}\,{}^3x_1^0 r^\pi_{31_1}\left({}^1x_1^1\right) r^\pi_{31_2}\left({}^1x_2^1\right) r^\pi_{31_3}\left({}^2x_3^1\right)$,

${}^3\widehat{x}_2^1 = r^\pi_{33_1}\,{}^3x_2^0 r^\pi_{31_1}\left({}^1x_4^1\right) r^\pi_{31_2}\left({}^1x_5^1\right)$, ${}^3\widehat{\pi}_O = {}^3\widehat{x}_1^1 r^\pi_{33_2}\,{}^3\widehat{x}_2^1$.

The obtained O-situation forms some P-situation ${}^1\Pi_P = ({}^1x_1^1 r^\pi_{11_2}\,{}^1x_2^1)\ ({}^1x_3^1 r^\pi_{11_3}\,{}^1x_4^1)\ ({}^1x_3^1 r^\pi_{11_4}\,{}^1x_5^1)$. This allows to compute *value* ${}^5x_\omega^0$ of characteristic *mode* ${}^{212}x_\mu^\pi$. Then CI of the state of CO is $s(t) = {}^3\widehat{\Pi}_O\,{}^1\Pi_P({}^{212}x_\mu^0 r^\pi_{25_1}({}^5x_\omega^0)) = {}^3\widehat{\pi}_O\,{}^1\Pi_P = ({}^3\widehat{x}_1^1 r^\pi_{33_2}\,{}^3\widehat{x}_2^1)\ ({}^1x_1^1 r^\pi_{11_2}\,{}^1x_2^1)\ ({}^1x_3^1 r^\pi_{11_3}\,{}^1x_4^1)\ ({}^1x_3^1 r^\pi_{11_4}\,{}^1x_5^1)({}^{212}x_\mu^0 r^\pi_{25_1}({}^5x_\omega^0))$.

So, an expression about CI of a state includes: ${}^3\widehat{\Pi}_O$– AC "O-situation" over relations "action-action", ${}^1\Pi_P$ – AC "P-situation" over relations "resource-resource", $({}^{212}x_\mu^0 r^\pi_{25_1}({}^5x_\omega^0))$ – characteristic *mode* ${}^{212}x_\mu^0$ with computed *value* ${}^5x_\omega^0$ over relations "resource-property" for resources of P-situation. If we take into account, that ${}^3\pi_0$ is considered within the context of productive structure, then knowing $s(t_O)$ we can predict the behavior of CO in the next moment of the time t_1, i.e. $s(t_0) \longrightarrow s(t_1)$, where $t_1 > t_0$.

V. The grammar of identical transformations and functional deformation of a co-cognitive image of a state

R1. If AC in ${}^iX$ or ${}^iX^n$ has AF of view $\left({}^ix_m^0 r^\pi_{\mathrm{ij}_l}\,{}^jA\right) | i \neq j,$ then it can be converted to the view $r^\pi_{\mathrm{ij}_l}\left({}^jA\right)$ and on the contrary, if AC contains BF $r^\pi_{\mathrm{ij}_l}\,{}^ix_m^0$ and AF $r^\pi_{\mathrm{ij}_k}\left({}^jA\right)$, then the last one can be transformed as follows $\left({}^ix_m^0 r^\pi_{\mathrm{ij}_k}\,{}^jA\right)$. For example:

$$
\begin{aligned}
{}^1x_1^1 = {} & r^\pi_{11_1}\,{}^1x_1^0({}^1x_1^0 r^\pi_{12_1}(r^\pi_{22_1}\,{}^{213}x_1^0({}^{213}x_1^0 \\
& \left({}^{213}x_1^0 r^\pi_{25_1}\,{}^5x_1^0\right)))
\end{aligned}
$$

$$
({}^1x_1^0 r^\pi_{12_1}(r^\pi_{22_2}\,{}^{211}x_1^0\left({}^{211}x_1^0 r^\pi_{24_1}\,{}^4x_1^0\right)\left({}^{211}x_1^0 r^\pi_{25_1}\,{}^5x_2^0\right)))
$$

it can be replaced by

$$
\begin{aligned}
{}^1x_1^1 = {} & r^\pi_{11_1}\,{}^1x_1^0 r^\pi_{12_1}((r^\pi_{22_1}\,21^3\,x_1^0 r^\pi_{25_1}\,{}^5x_1^0) r^\pi_{12_1} \\
& \left(r^\pi_{22_2}\,{}^{211}x_1^0 r^\pi_{24_1}\,{}^4x_1^0 r^\pi_{25_1}\,{}^5x_2^0\right)
\end{aligned}
$$

. R2. If AF of the view $r^\pi_{\mathrm{ij}_l}\left({}^jA\right)$ contain the same relation, then it can be put out of the bracket (the reverse is also true):

$$
\begin{aligned}
{}^1x_1^1 = {} & r^\pi_{11_1}\,{}^1x_1^0 r^\pi_{12_1}(\left(r^\pi_{22_1}\,21^3\,x_1^0 r^\pi_{25_1}\,{}^5x_1^0\right) \\
& \left(r^\pi_{22_2}\,21^1\,x_1^0 r^\pi_{24_1}\,{}^4x_1^0 r^\pi_{25_1}\,{}^5x_2^0\right)).
\end{aligned}
$$

R3. If in AC ${}^ix_m^n$ there is a string of defining concepts $({}^jD)$ and $i \neq j$, then ${}^jx_k = \left({}^jD\right)$ can be imposed and $\left({}^jD\right)$ can be replaced by ${}^jx_k$. The reverse is also true. For example:

${}^2x_1^1 = \left(r^\pi_{22_1}\,{}^{213}x_1^0 r^\pi_{25_1}\,{}^5x_1^0\right)$. If we impose ${}^2x_2^1 = \left(r^\pi_{22_2}\,{}^{211}x_1^0 r^\pi_{24_1}\,{}^4x_1^0 r^\pi_{25_1}\,{}^5x_2^0\right)$,

then ${}^1x_1^1 = r^\pi_{11_1}\,{}^1x_1^0 r^\pi_{12_1}\left({}^2x_1^1\,{}^2x_2^1\right)$.

R4. If in ${}^ix_m^\pi$ there is subsidiary feature $r^\pi_{\mathrm{ij}_l}\left({}^jA\right)$, where $r^\pi_{\mathrm{ij}_l} \in {}^5R^\pi_{\mathrm{ij}}$ and in ${}^jA$ there is a string of defining concepts ${}^jD$, then we can impose ${}^jx_k = {}^jD$ and replace ${}^jD$ by ${}^jx_k$, and also replace ${}^jx_m^n$ by ${}^jx_m^{n+1}$. The reverse is also true. For example:

$$
\begin{aligned}
{}^1x_1^1 = {} & r^\pi_{11_1}\,{}^1x_1^0 r^\pi_{12_1}({}^2x_1^1\,{}^2x_2^1\,{}^2x_3^1) \\
& r^\pi_{11_2}(r^\pi_{11_1}\,{}^1x_2^0 r^\pi_{12_1}({}^2x_3^1\,{}^2x_4^1\,{}^2x_5^1) \\
& r^\pi_{11_1}\,{}^1x_3^0 r^\pi_{12_1}({}^2x_6^1\,{}^2x_7^1),
\end{aligned}
$$

Impose

$$
\begin{aligned}
& {}^1x_1^1 = r^\pi_{11_1}\,{}^1x_2^0 r^\pi_{12_1}({}^2x_3^1\,{}^2x_4^1\,{}^2x_7^1), \\
& {}^1x_2^1 = r^\pi_{11_1}\,{}^1x_3^0 r^\pi_{12_1}({}^2x_6^1\,{}^2x_7^1), \\
& {}^1x_1^2 = r^\pi_{11_1}\,{}^1x_1^0 r^\pi_{12_1}({}^2x_1^1\,{}^2x_2^1\,{}^2x_3^1) r^\pi_{11_2}({}^1x_1^1\,{}^1x_2^1)
\end{aligned}
$$

R5. If $r^\pi_{\mathrm{ij}_l}$ is symmetric, i.e. $r^\pi_{\mathrm{ij}_l} = \frac{1}{r^\pi_{\mathrm{ij}_l},}$ then $({}^1D_k\ r^\pi_{\mathrm{ij}_l}\ ({}^jD_m)) \in {}^i\Pi$ can be replaced by $({}^1D_m\ r^\pi_{\mathrm{ij}_l}\ ({}^jD_k))$. If $r^\pi_{\mathrm{ij}_l}$ is asymmetric, i.e. from two rations $({}^1D_k\ r^\pi_{\mathrm{ij}_l}\ {}^jD_m)$, $({}^1D_m\ r^\pi_{\mathrm{ij}_l}\ {}^jD_k)$ at least one is not completed and $\overline{r}^\pi_{\mathrm{ij}_l} = \frac{1}{r^\pi_{\mathrm{ij}_l},}$ then $({}^1D_m\ \overline{r}^\pi_{\mathrm{ij}_l}\ ({}^jD_k)) \in {}^i\Pi$. For example: if we have $({}^1x_1^1 r^\pi_{11_5}({}^1x_2^1))\left({}^1x_3^1 r^\pi_{11_6}({}^1x_4^1\right) \in {}^1\Pi$ and $r^\pi_{11_5}$ is symmetric and $r^\pi_{11_6}$ is asymmetric, then $({}^1x_2^1 r^\pi_{11_5}({}^1x_1^1))\left({}^1x_4^1 \overline{r}^\pi_{11_6}({}^1x_3^1)\right) \in {}^1\Pi$.

R6. If $({}^iD_n\ r^\pi_{\mathrm{ij}_l}\ ({}^iD_m))$, $({}^iD_n\ r^\pi_{\mathrm{ij}_l}\ ({}^iD_f)) \in {}^i\Pi$, then they can be replaced by

$({}^iD_n\ r^\pi_{\mathrm{ij}_l}\ ({}^iD_m\,{}^iD_f)) \in {}^i\Pi$. The reverse is also true. For example: if we have $({}^1x_1^1 r^\pi_{11_5}({}^1x_2^1))\left({}^1x_1^1 r^\pi_{11_5}({}^1x_3^1\right)\ \left({}^1x_1^1 r^\pi_{11_5}({}^1x_4^1)\right)$, it can be replaced by $({}^1x_1^1 r^\pi_{11_5}({}^1x_2^1\,{}^1x_3^1\ {}^1x_4^1))$.

R7. If left poles of AC in ${}^i\Pi$ identical, then they can be put out of the bracket. The reverse is also true. For example: $({}^1x_1^1 r^\pi_{11_5}({}^1x_2^1))({}^1x_1^1 r^\pi_{11_6}({}^1x_3^1))$ can be replaced by $({}^1x_1^1(r^\pi_{11_5}({}^1x_2^1) r^\pi_{11_6}({}^1x_3^1))$. Putting out of right poles comes down to the R5,7.

The following group of rules is used for the functional deformation of the semantics of the entropy, cognitive image of the CO state into the regulatory, pragmatic information of a concise and localized operational image. The moment of display to the human-operator of the operational image is calculated by the "resource-property" relations, based on the establishment of a "threshold" of operation. If the threshold value is reached, then the cognitive image is deformed as a sign of the operational image. Since according to relations “property-resource” we know those resources in ${}^{1}\Pi_{P}$, properties of which are out-of-range (emergency resources; let it can be only one), then first of all, ${}^{1}x_k^n{=}^{j}D_k$ is reduced by extraction from ${}^{j}D_k$ irrelevant features from AF (by the rule R8). After that the spatial structure ${}^{1}\Pi_{C}$ of CO is reduced to a fragment, containing information only about the position of emergency resource in its real nearest environment. In addition, because an emergency resource performs a particular role by relations “resource-action” within an action in O-situation${}^{3}\Pi_{O}$, it is connected by relations “resource-resource” with other resources from ${}^{1}\Pi_{P}$. That’s why a sign ${}^{1}\Pi_{P}$ is reduced within the rule R9.

R8. If for an operation ${}^{3}x_f^n$ one involve resources ${}^{1}\widetilde{x}_1^n, {}^{1}\widetilde{x}_2^n, \ldots, {}^{1}\widetilde{x}_m^n,$ then from ${}^{1}\Pi_{c}$ a fragment ${}^{1}\,\widetilde{\Pi}_c$ can be cut. The last contains links only of ${}^{1}\widetilde{x}_1^n, {}^{1}\widetilde{x}_2^n, \ldots, {}^{1}\widetilde{x}_m^n,$ between each other. All other links ${}^{1}\Pi_{c}$ are not significant. For example, if ${}^{1}\,\widetilde{\Pi}_c$ = $\left({}^{1}x_1^1 r_{11_5}^{\pi}\,{}^{1}x_2^1\right)\left({}^{1}x_3^1 r_{11_5}^{\pi}\,{}^{1}x_4^1\right)$, then taking into account the previous example for ${}^{3}x_1^1$ we get ${}^{1}\,\widetilde{\Pi}_c = \left({}^{1}x_1^1 r_{11_5}^{\pi}\,{}^{1}x_2^1\right)$. Because resources ${}^{1}x_1^n, {}^{1}x_2^n, \ldots,\ {}^{1}x_m^n$ form a P-situation ${}^{1}\Pi_{p}$, then exactly this P-situation defines the cut fragment ${}^{1}\,\widetilde{\Pi}_c$.

R9. Every AC of a cognitive image $s\,(t) \quad =^{3} \widehat{\Pi}_O{}^{1}\Pi_{P}\ \underline{({}^{212}x_\mu^0 r_{25_1}^{\pi}({}^{5}x_\omega^0))}$ can be distorted into AC of an operational image ${}^{3}\widetilde{\widehat{\Pi}}_o{}^{1}\,\widetilde{\Pi}_p({}^{212}x_\mu^0 r_{25_1}^{\pi}({}^{5}x_\omega^0))$, if $\{{}^{1}D_{p}\}$ has been fragmented within the rule R8.

VI. Conclusion

Cognitive hybrid intellectual systems are proposed for computer simulation of cognitive formations and enhancing human intelligence in operational work, by supplementing the natural abilities of the operator (in the work with operational-technological information) with software and hardware that expand the human mental processes. In relation to them, a language has been developed for describing relations and links for predictive coding of word-verbal knowledge about resources, properties and actions of personnel. There also has been developed a grammar of identical transformations and functional deformation of the semantics of the entropy, cognitive image of the state of a control object into regulatory, pragmatic information of concise and localized operational image.

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Предикативная модель когнитивного и оперативного образа объекта оперативно-технологического управления (ОТУ) в системах с высокой динамикой

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Для компьютерной имитации когнитивных образований и усиления человеческого интеллекта в оперативной работе, путем дополнения естественных способности оператора к работе с оперативно-технологической информацией, программно-аппаратными средствами, расширяющими мыслительные процессы человека предложены когнитивные гибридные интеллектуальные системы. Применительно к ним разработан язык описания отношений и связей для предикативного кодирования словесно-вербальных знаний о ресурсах, свойствах и действиях персонала, грамматика тождественных преобразований и функциональной деформации семантики энтропийного, когнитивного образа состояния объекта управления в регуляритивную, прагматическую информацию лаконичного и локализованного оперативного образа.

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