Conceptual Modeling of Intelligent Systems Components and Functionality

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Abstract. The intelligent systems unified architecture proposed for comprehensive modelling the subject domains specialists' activities in professional tasks solving. The human thinking processes and memory structures invariants adapted to given activity areas form foundations for such modelling. The structural and functional aspects of proposed architecture developed by integrating the entities of different models in mathematics, cybernetics, system engineering, linguistics and cognitive science. Such architecture components formalized specifications make a basis for creating the uniform descriptions of formalized cross-disciplinary intelligent systems models. They allow further transforming into intelligent systems' applied prototypes with unified common structural and functional properties. These prototypes based on the principles of knowledge engineering and able to accumulate specialist's experience in keeping and processing the complex knowledge structures. The developed models allow consider the thinking processes invariants as a basis for technology of designing the intelligent systems at specialists' activity areas. The proposed intelligent systems developed as results of adaptation the thinking processes' and memory structures' universal invariants. They allow performing complete simulation the subject specialists' professional activity. Mathematical basis for described intelligent systems' models originates from abstract concept of knowledge representation formalism. These formalisms' invariants, used as basic for formal specifications of nonmathematical concepts, essential for representation the human memory structures and thinking processes. Intelligent systems' universal components form uniform structure. The last one based on knowledge dimension concept and realized by knowledge flows that cross separate dimensions and performed within such a structure.

Keywords: intelligent system, subject area, knowledge representation formalism, cognitive goal, cognitive synthesis, ontology, knowledge processing operation, knowledge-processing diagram, knowledge flow.

1 The Intelligent System's Dimensions and Levels Structure

Intelligent system concept comprehensive description assumes joint reflection the entities of multiple models, proposed for knowledge representation and processing at cognitive science [1, 2 and 3], linguistics [4], systems engineering [5] and mathematics [6, 7]. General intelligent system concept suppose applying the complete set of independent knowledge attributes considered as having key priority at scientific areas concerned on studies the knowledge [8]. Separate dimension's meanings called quants. They form ordered set of knowledge attribute's possible meanings and distributed through levels, associated with knowledge quants sets. Quants adopted as knowledge fundamental parameters meanings. They form formalized knowledge dimensions. Dimensions and their meanings grouped into possible knowledge aspects' combinations that define components for designing the intelligent systems models. Dimensions and their quants form universal components' cellular structure as unified base for the various intelligent systems and processes' models developing at different activity areas. The models elements define intelligent systems' entities formal specifications. The last ones allow representing and processing these elements distributed among components' cellular structure. Number of dimensions used at intelligent system defines its complexity. The new dimensions' introducing imply growing possibilities for knowledge representing and processing. The two-dimension case of intelligent system architecture would considered below. It based on cognitive and linguistic aspects of knowledge measured in appropriate ways.

1.1 The Intelligent System With Two Dimensions Architecture

The two-dimension intelligent system architecture considered below. It relates to aspects of knowledge representation abstractness and atomization. The aspect of knowledge representation abstractness is similar to K. Stanovich idea of multilevel architecture for one-dimension intelligent system. This architecture based on modeling the knowledge semantic structures and knowledge processing operations that correspond to human memory structures and thinking processes [3]. Such architecture uses three levels for dimension of human thinking abstractness called as reactive, algorithmic and abstract memories. These levels represented by vertical direction of intelligent systems components' cellular structure (see Fig. 1).

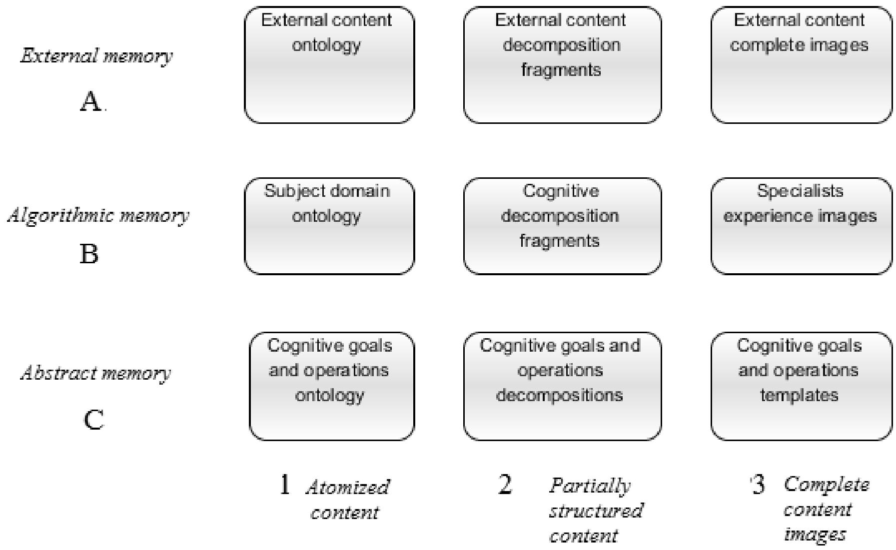

Fig. 1. Intelligent system two-dimension components structure

The structure’s horizontal dimension quants correspond to knowledge representations decomposition degree meanings. These meanings form second dimension of intelligent systems' structures. The dimension values allow to apply the new significant attribute of subject area (SA) content representation. It associated with various subject areas' content decomposition formats properties. Knowledge quants define following considered dimension's meanings: completely atomized (expressed by ontology representation close to descriptive logics' formats), partially broken (intermediate formats with knowledge aggregates, useful for subsequent assembling into complex knowledge images) and full images (complete representations of subject area content fragments realizations). The intersections of horizontal and vertical lines assigned to dimensions' fixed quants define components of intelligent systems cellular structure. They allow modelling specialists’ activity that based on human mind memory and operations structures adapted to selected quants meanings.

Components established on Fig. 1 addressed as two-dimension structures elements defined by rows and columns' quants meanings A, B, C and $1, 2, 3$. Every structure’s component has internal memory constructed as collection of information areas. They joined into semantic representation used for modeling the knowledge-based processes assigned to component and performed by intelligent agents. The components' memory unified structure includes two subareas called as component's processes area and component's ontology. The first designated area intended for complex knowledge structures' synthesizing within it. Component's memory contains knowledge structures sequences constructed within component as knowledge processing representations. The second memory area contains component's ontology. It supplies component's intelligent agents with elementary and simple knowledge used for synthesizing complex knowledge. Ontology accumulates elementary and simple knowledge associated with component. Knowledge used for modeling processes of SA problems solving.

1.2 External Mind Level Basic Features

External memory level proposed for modeling the processes of interaction with external entities of knowledge area's content representation. Such content exists outside the intelligent system and presented by knowledge-containing resources. These resources' formats, adopted by specialists involved into tasks solving activities within given area. Initial placing for such content performed at component called external content complete images as part of structure in Fig.1. Information objects placed in this component presented in formats that external for intelligent system. Objects' applying demands their further transforming into intelligent system internal structures. The offered quants of knowledge decomposition dimension allow performing such transformation in several steps. They based on images decomposition from weakly structured texts, pictures, sounds and other possible types for subject domain knowledge and empirical data representation. Decomposition performed into elementary, simple and complex knowledge structures. Every object placed into component's memory described as its elements' semantic structure, recognized in algorithmic way by component agents.

Knowledge representation formalisms' invariants form abstract ground of uniform internal formats constructing for knowledge representation at intelligent systems [7, 8]. The invariants’ list includes concepts of knowledge fragment, fragment algebraic and semantic structures [7]. The uniform knowledge formats for intelligent systems components that considered in further relate to formalisms of semantic hierarchies' [8, 9]. These formalisms define unified knowledge representation format as binary tree's structure with vertices named as binary sequences that specify ways from the tree root to vertices. The semantic hierarchy's leaves are marked with elementary knowledge (as names or formal symbolic expressions). The trees internal vertices marked with semantic relations that carried out between knowledge represented by vertices' left and right subtrees. Separate knowledge of such formalism represented by unique hierarchy. Algorithm that constructs such hierarchy realizes recursive scheme of knowledge step-by-step decomposition. Sets of abstract knowledge (M), knowledge with fixed structure depth k (M_k) and knowledge algebraic structures (Σ_k), where $k \in \{1, 2, ...\}$, define data types for knowledge processing morphisms' domains and ranges. Unstructured knowledge $z \in M$ transformed into formats of semantic hierarchies by decomposition of $A3$ elements. It uses intermediate content decomposition into combinations of fragments and recognizing semantic relations between them. Such decomposition performed at $A2$ component. Fragments transformed into elementary (indivisible) and simple knowledge (semantic relations between pairs of elementary knowledge). They form subject area's external ontology placed at $A1$ component's memory. Subject area external ontology formed as result of complete input entities decomposition that describes current situation and prepared for further analysis.

Knowledge maps are convenient as main ontology's representation format at that paper. Every map defined as finite set of finite classes filled with elementary knowledge. Semantic relations between classes expressed by arrows and marked by relations' names. The structure of memory for external mind level component $A3$ includes substructure for component's ontology. That allows classifying and comparing the external subject area content's entities. These problems solved by processes of external entities placing and further activating intelligent agents of content's containing entities processing. The ontology area at $A2$ component contains knowledge used for decomposing the subject domain's resources into formats similar to semantic hierarchies. Such ontology accumulates properties about knowledge semi-structured representations that used by content's decomposition algorithms. Possible classes of elementary knowledge within last ontology realize as properties of knowledge decompositions as knowledge about integrating of decomposition parts. Such integrating describes external content parts transformation, performed into semantic hierarchies' formats. The knowledge representation format for subject domain content based on elementary knowledge expressed by names and mathematical (formal) expressions. They form SA content complete formal description. Following general classes' worthy for inclusion into component ontology: *separate keywords*, *keywords combinations*, *structural parameters*, *parameters meanings*, *combinations-recognizing conditions*. Example of such ontology presented on Fig. 2.

Subject area content expressed by classes and relations given on that figure realizes goal of unstructured external entities content transformation into format similar to semantic hierarchies. Such decomposition realized by partition procedure. It based on knowledge fragments extraction, properties recognizing and subsequent linking fragments pairs by semantic relations. Such procedure's variant based on down-up scheme and begins with indivisible knowledge representation elements (atoms). Atoms form special class of knowledge explicit representations (by names) as vocabulary elements and classified by several general types. Atoms' neighborhoods and atoms combinations in unstructured knowledge used for recognizing the low-level knowledge fragments.

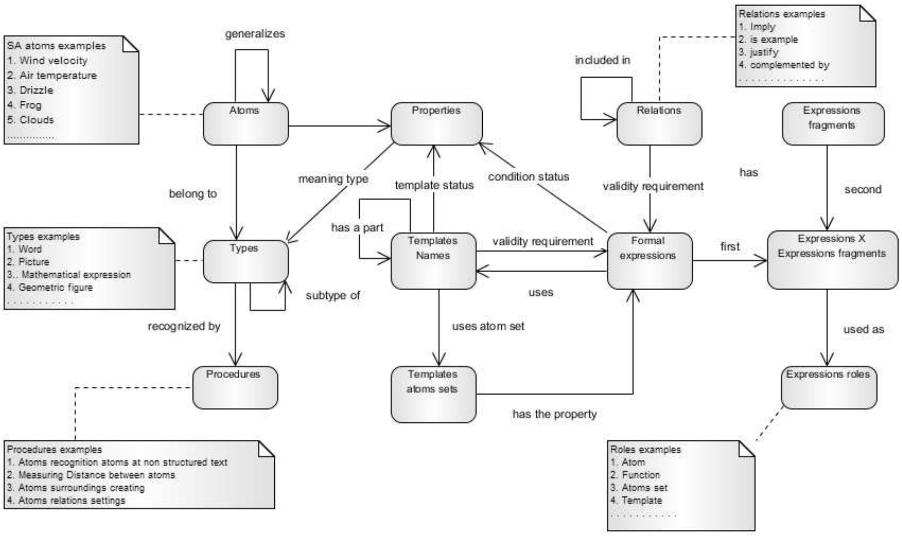

Fig. 2. The knowledge fragments decompositions ontology of external memory level

The templates' atoms set intended for fragments classifying. Knowledge fragments based on atoms sets allow creating the atoms' combinations. These combinations realized by "Templates Names" class are used for description the significant semantic structures. They represented by templates combinations and integrated into intermediate substructures formatted as semantic hierarchies. The class "Procedures" contains names of ontology-based procedures. They perform unstructured knowledge representations decompositions at $A2$ by intelligent agents.

The ontology main area provides possibility of formalized mathematical content processing. It allows construct and apply complex knowledge' formal descriptions. Class "Formal expressions" used for SA resources decompositions elements properties description. It linked to classes "Templates Names" and "Templates atoms set" by relations "has the property" and "validity requirement". Essential aspect of mathematical expressions embedding into ontology consists in expanding the possibility of abstract designating for SA entities. For that case, all mathematical expressions that apply abstract notations for elements of SA content supplied with their interpretation by symbolic expressions' fragments roles. The picture elements drawn as notes-sheets represent the fragments of classes. Various information about mathematical expressions properties may be included into ontology by assigning to expressions' fragments their properties. Mathematical expressions also make possible the application of abstract entities' infinite sets for algorithmic constructing or recognizing such entities' properties. For example, let us consider mathematical expressions' recurrent descriptions. They used for formal symbolic expressions' classification and based on ontology elements' combinations that allow descriptions' analysis. The following formal rules demonstrate examples of symbolic expressions for knowledge representation format at ontologies: *polinom* "*is defined as*" ax^n and *polinom* "*is defined as*" $P(x)+ax^n$, where ax^n and $P(x)+ax^n$ − mathematical expressions. The set of simple knowledge at ontology allow specify the expressions' fragments properties by such simple knowledge as

a "is" *real number*, x "*is*" *variable*, n "*is*" *integer number* and $P(x)$ "*is*" *polinom*.

The external memory $A1$ component saves results of SA content's complete decomposition. Elementary and simple knowledge extracted from external unstructured entities and form E –ontology. Such ontology accumulates knowledge formed by unstructured knowledge representations' complete decomposition operations. The E -ontology elements prepared by intelligent agents of $A2$ component. Component $A1$ structure consists of several subareas. They accumulate results of subject domain content's complete decomposition needed for further transforming the SA ontology caused by changes in E − ontology. These component's agents recognize simple knowledge with different statuses. Knowledge statuses' detailed system contained at [10].

Two basic knowledge statuses possible: *current situation* and *new knowledge*. These statuses defined by knowledge source classification and represented by special sets of simple knowledge. The current situation's status defines initial data for ontology based subject area tasks solving. The ontology processing includes new tasks recognizing and their following realization by complex knowledge synthesis based on tasks' solution templates. The statuses of new knowledge recognized by additional analysis of synthesized knowledge and SA ontology. It implies appropriate ontology's transformations.

1.3 Algorithmic Mind Level Specification

The algorithmic memory level's application relates to modeling professional tasks' algorithmic solving by intelligent agents associated with this level's components $B1$ - $B3$. The $B1$ used there as foundation of knowledge processing and based on SA ontology. It includes complete current knowledge area content decomposition received by processing the E -ontology presented at $A1$. The SA ontology splits onto several uniform areas given below (see Fig. 3).

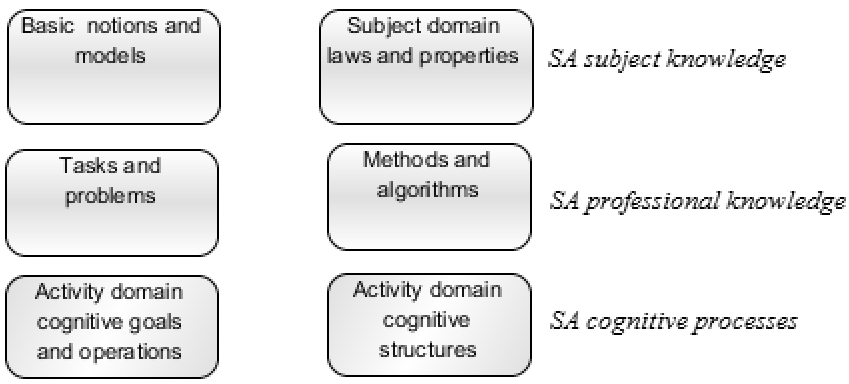

Fig. 3. Subject area ontology unified subareas

These subareas simulate the specialists' knowledge structures used for subject area problems solving. They based on combining the different thinking operations associated with specialists' cognitive goals. The ontology subareas realize ontology's splitting in separate fragments and simplify subareas' independent development and interaction. The subareas form ontology general structure. This structure reflects specialists' experience and cognitions. The subarea of subject knowledge integrates knowledge relating to rules, models and notions that exist independently to specialists' possible professional activity. Subarea of professional knowledge accumulates formalized knowledge about ways of the subject area's tasks solving by specialists. Such knowledge allows recognizing the activity area tasks for their following modeling by intelligent system agents. The professional knowledge descriptions include mathematical expressions as part of formally defined set of elementary knowledge. Expressions initiate developing the SA professional tasks solved by knowledge-based processes applying mathematical formulas transformation and analysis techniques. Considered intelligent systems architecture create possibilities of professional tasks solving within knowledge driving models. The properties and laws ontology subarea accumulates basic knowledge for ontology-based tasks solving. This subarea's knowledge applied within cognitive processes modelling. Cognitive processes area of SA ontology includes information necessary for analysis the knowledge correctness, redundancy and completeness, providing knowledge generalization and compression within ontology.

Relations between classes of separate subareas represent the ontology subareas' external communications. Such classes declared as boundary with special rules for assigning this status. Classes save their status when ontology's subarea transformed into new variant one with modified subarea's classes and semantic relations.

Component $B2$ intended for simulating the tasks solving processes called as knowledge series [6]. Intelligent agents generate these series independently as realizations of separate intelligent system goals. Agents' activity consists in selecting and performing the templates that describe the complex knowledge synthesis processes' structures. Templates defined as combinations of knowledge processing operations [8]. The tasks' solving by knowledge evolutions then transformed into format of specialists' experience images and transferred into $B3$ component. These images extracted in form of knowledge evolutions' subsequences by tracings' operations of synthesized knowledge algebraic structures [9, 10]. Images form domain for intelligent system's experience in tasks' solving. It accumulates the system's experience that transformed into subject area knowledge external formats or goals and operations' templates. First case has several aspects. They vary from simple case of external area actual problem complete decision to dialog-based long communication with external area entities.

1.4 Parameters of Abstract Mind's Level

Components of abstract memory supply intelligent system with entities that define abstract invariants for modelling knowledge representation formats and morphisms for simulating the intelligent system functional aspects. They define the intelligent system mathematical base that allows the experts' abstract knowledge coordinating with linguistic and cognitive science's entities. Mathematical invariants' coordination with cognitive aspects of knowledge processing modeling based on classifiers for goals and operations as thinking processes' elements. The intuitively complete basic system of cognitive goals introduced by B. Bloom and revised by D. Krathwohl. It includes next goals: understanding, remembering, applying, estimating, generalizing, analysis and synthesis [1, 2].

Listed goals types have semi-formal description. That makes it possible to consider them as independent and useable for creation complex goals descriptions scenarios, with basic goals as elements. Cognitive operations associated with ways for goals realizations by diagrams designed as compositions of abstract mathematical operations. Diagrams describe sequences of algebraic operations that provide processing the knowledge representations as cognitive operations realization. The three components of abstract mind level correspond to quants of knowledge decomposition dimension. The component of complete abstract knowledge ($C1$) used for accumulating goals and operations' descriptions. They placed in two subareas of component. Knowledge representation formalisms' invariants form basis for goals' and operations' formal descriptions [6].

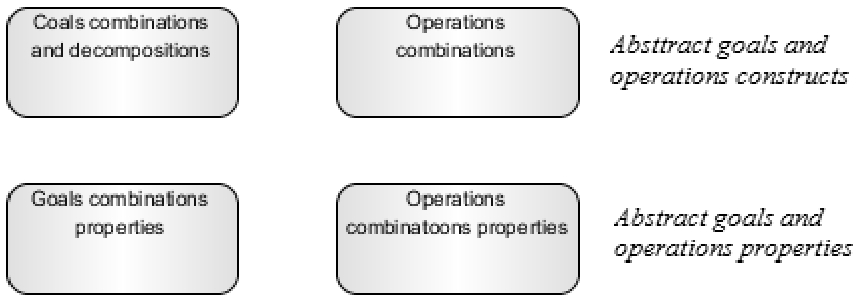

Fig. 4. The cognitive goals and operations component's structure

The $C1$ component used for abstract goals and operations' combining into knowledge processing structures. This allow define processes formal descriptions as operations combinations (see Fig. 4). The subareas content as extracted from structures presented at $A2$ component transformed gradually into knowledge representation formats for $B2$ and $C2$ components. Selecting appropriate goals and operations for SA tasks' solving uses such goals and operations' combinations properties. Such properties obtained by analysis the cognitive structures that extracted from $B2$ and generated as templates based professional tasks solving processes. The $C3$ component contains templates of abstract goals realizations. They transformed into images of abstract scenarios for SA tasks' solving.

2 Intelligent Systems' Knowledge Processing Diagrams

Formal basis for unified intelligent system architecture and knowledge representation formats depends on operations, used at abstract mathematical models. Operations' unified format suppose that they are unary with only exception of binary composition operation. Last operation allows integrating different objects into their direct sums and used as knowledge representation formalisms' invariant.

General formats for knowledge flows and processes descriptions define them as knowledge transforming within and transferring between architecture's components.

Such flows structure demonstrates knowledge processing stages as its transformation or transferring by transition between components that are neighbors in one dimension. Computable algebraic operations with given domains and ranges simulate knowledge transformations. They based on unified content's representation formats for intelligent system components' memory. Operations are integrated at classes and analogous to wide spectrum of abstract operations proposed within fundamental mathematical models. They have exact semantics based on operations' formal descriptions. Example of algebraic operations classes' hierarchy useful for knowledge presented by their algebraic structures exists [7].

Scenarios look like oriented graphs (diagrams) with vertices, marked by names of operations classes. Abstract scenario formal description realize proposition that one operations class originates elementary scenario, formed by one diagram vertex marked with class name. Complex scenario looks as combination of elementary scenarios, connected by directed edges in such way that if vertices marked with classes F_1 and F_2 joined by directed edge, where F_1 and F_2 contain operations, represented by functions with format $f: X \to Y$ and $\varphi: Z \to U$ correspondently, then $Y \subseteq Z$. Last condition allows considering any path on marked graph as composition of operations belonging to classes assigned to path's vertices. Diagram defines sequences of operations used as foundation for further developing into exact description of goal's realization process. General unified abstract scenario for any SA problem solving, represented, as example, by sequence of three consequently performed operations from classes of knowledge selection (E), logical and algebraic adaptation ($AA \cup LA$) and tracing (TA) [8]. Abstract scenario's diagram presents knowledge-based process' initial description that allows transforming into diagram's homomorphic extensions. Such transformations performed in several steps. They lead to gradual extending process's description by parameters' additional specifications. The diagram's homomorphic extensions implemented by operations of process model parameters' adding, splitting and restriction. These operations allow diagrams' transforming into their detailed descriptions with last diagrams' inverse transformation into previous diagrams by diagrams' homomorphisms. The first operation introduce into processing the new attributes that extend the diagrams' and diagram elements structure with additional parts. This allows new parameter embedding into diagrams' descriptions. Second operation relates to diagram's existing attributes. They structured by splitting on components with possibility of these components' values transforming backward into whole ones. The parameters' restriction operations served as tool for attributes' values domains narrowing for initial diagrams' transformation into their more exact variants. All these operations allow inversions and their compositions define diagrams homomorphisms by compositions of homomorphic extensions' inversions. Operations combinations define the operations' complex descriptions for goals' realization diagrams. Operations' general descriptions identify operations' properties and presented by formal expressions. Abstract operations classification allows create hierarchies of scenarios as defined bellow. Let $\Phi = \{F_1, ..., F_n\}$ – is a set of basic operations classes structured as hierarchy by classes' inclusion relation, $\Xi = \{\sigma_1, ..., \sigma_m\}$ – is a set of operations scenarios and $\mu_i : V_i \to \Phi$ – mapping, which defines Φ elements, assigned to σ_i vertices. We say that diagram σ_j more general in comparison with diagram σ_i (designate that fact as $\sigma_i \subseteq \sigma_j$) if and only if diagrams graphs are isomorphic and for some mapping $\psi : V_i \to V_j$, that establish their isomorphism, the condition satisfied $\forall v \in V_i(\mu_i(v)) \subseteq \mu_j(\psi(v)))$.

Diagrams' homomorphisms and homomorphic extensions provide wide possibilities for knowledge processing diagrams abstract and applied simulation and analysis. Such extensions' variants given on next figure (see Fig. 5).

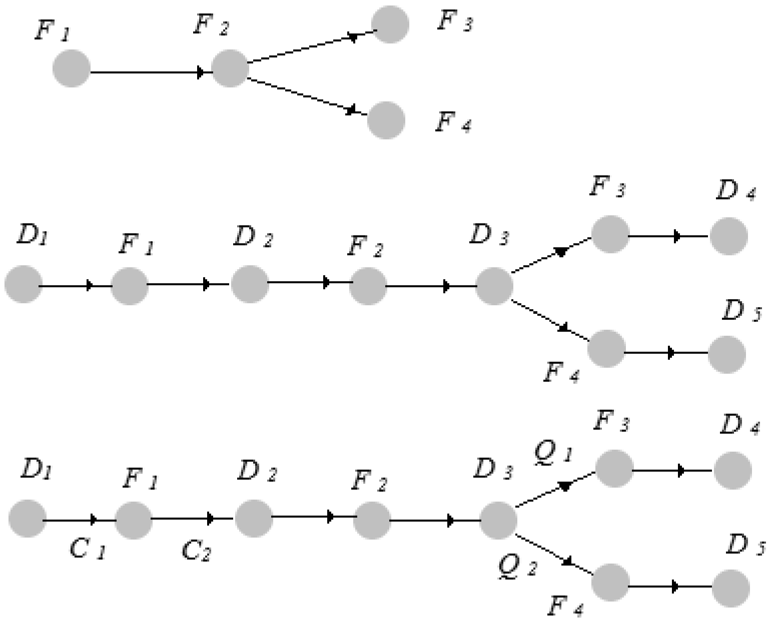

Fig. 5. Knowledge processing diagrams extensions

Diagrams constructed of two kinds of elements (vertices and directed arrows). In such format they seemed too abstract and weakly compliant with cognitive processes reality. The abstract diagram's transforming into SA task solving knowledge-based process may demand performing a long sequence of extensions. They perform diagram's direct transforming into such one that sets exact knowledge processing description and has algorithmic realization. The first diagram as abstract diagram. It presented by graph with vertices marked by operations classes' names. Such diagram extended by operations' domains and ranges. New diagram presents the initial diagram's homomorphic extension. Such diagram's format based on initial diagram extension by adding new vertices. They extend the vertices' selected properties by pointing out the domains and ranges for classes of operations assigned to initial diagram's vertices. The last diagram demonstrates diagram developing by adding conditional expressions associated with diagram's arrows. Conditions inserted into diagrams allow describes different ways of diagrams' applications when solving *SA* tasks. Separate conditional expression allows inclusion into diagram with additional attribute of its role. This attribute specifies way of condition interpreting by intelligent systems' processes modeling algorithms. Expressions C_1 and C_2, attributed to the considered picture third diagram's arrows, interpreted as condition for permission the F_1 activation over input position content and for allocating the operation's result as content at output position. Expressions Q_1 and Q_2, attributed to the diagram's arrows, allow considering as independent cases for F_3 or F_4 activating. The list of given conditions expressions' is not complete. Their exact formal description suppose unambiguous executing. This demands consecutive specifications for conditions' roles system that blocks the inaccuracy in roles processing. Cases that demonstrate such and other possible diagrams homomorphic extensions and schemes for their inclusions into diagrams' descriptions presented on Fig. 6.

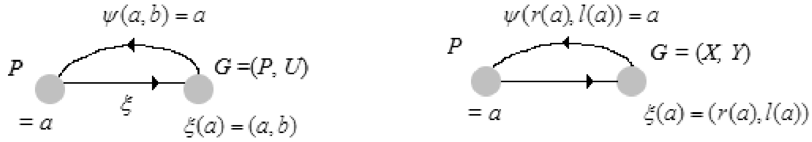

Fig. 6. Diagrams parameters extensions

Last figure illustrates two examples of attribute splitting. The left one illustrates new attribute U adding to existed attribute P that resulted by new attribute G as attributes' P and U combination. Pairs of attributes' values generated by appropriate homomorphic extensions (denoted as ξ). They define possible attribute U values for P given value a. The homomorphism that simulates inverse transforming of attribute G values is denoted ψ. Fragment on the right figure's side illustrates situation, when attribute P splitting onto pair of attributes X and Y takes place. Attribute values extended into pairs by mappings $l : P \to X$ and $r : P \to X$ that define first and second element of attribute G values associated with P values. Mapping ψ is homomorphism that performs inverse pairs' that form P values transformation into P initial values.

Diagrams' transformations based on attributes constraints described by conditional expressions. They present diagrams attributes' domains narrowing conditions and inserted into diagrams descriptions (see Fig. 7).

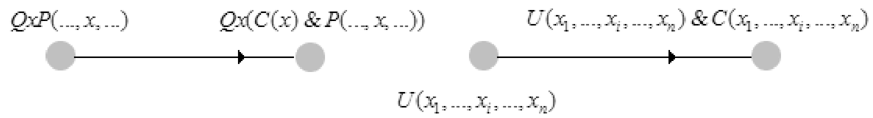

Fig. 7. Knowledge processing diagrams' attributes constraints

Subject area's driven constraints appeared by adding new conditional expressions as model's new properties descriptions. Added conditions modify *SA* content's representation within intelligent system's ontology into diagram's homomorphic extension.

Two examples of such extensions established in Fig. 7. The left one demonstrates case, when attribute (x) used as variable for predicate, represented by given expression under a certain quantifier $Q \in \{\exists, \forall\}$. Domain of variable's values added to system's properties descriptions and used by intelligent system's knowledge transforming algorithms. This allows creating operations' domains creating by additional constraints for considered domains elements' properties as defined by special predicates. General case of constraint represents the figure's right fragment. It based on joint restrictions for several SA attributes' values. Homomorphism that simulates inversion for considered diagrams transformation makes inverse of initial model attributes descriptions. Complete diagram’s description looks like initial diagram's transformations hierarchy.

Classifiers of intelligent system's operations define its functionality. Classification has finite depth and cover possible levels based on functional entities' algebraic structures complexity. The depth levels ordered by such complexity represented by Fig. 8.

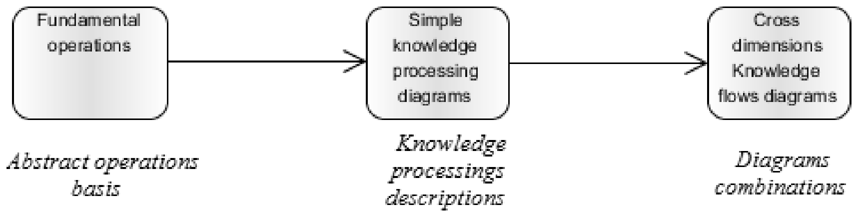

Fig. 8. Knowledge processing complexity levels

The first level includes morphisms for knowledge representation formalisms. Classes of morphisms and morphisms' domains and ranges look like mathematical category. It forms the intelligent systems' uniform abstract operations base. Knowledge processing diagrams for such level has one vertex that marked with one morphisms' class. Second level formed of knowledge-processing diagrams structured by relation of diagrams' gradual developing by diagrams’ transforming operations. Special morphisms of synthesis and decomposition are important there for creating operations' domains and ranges by knowledge structures integration and splitting. These morphisms allow modelling merging or parallelization of knowledge flows. Morphisms of composition and decomposition significant within mathematical models and allow different specifications. That extend their applications' variants. Diagram created as vertices sequences joined by arrows marked with transformations operations' descriptions used for modeling the functional infrastructures developing within intelligent system's components. Separate diagrams links with SA goals’ class elements expressed by relation “*associated with*”. The diagrams' sequences represent compositions of homomorphic extensions. They implement necessary growth the initial diagram's applications. The Fig. 8 right fragment based on diagrams’ combinations implemented as integrating the knowledge processing diagrams into knowledge flows templates. Considered levels define tools that allow knowledge-transforming specifications creating as basis for diagrams algorithmic realization when diagrams presented by mathematical descriptions. The knowledge transforming diagrams descriptions allow consider processes results as synthesized knowledge structures transferred through intelligent system's components. Each diagram associated with separate intelligent system component. Such diagram defines the component’s memory structure for saving elements appeared at diagram's operations domains and ranges. Knowledge flows' formal descriptions define localization for diagrams' operations domains and ranges at components' memory structures.

The diagrams' based knowledge processing uses diagrams' formal descriptions and operations' implementation algorithms. The knowledge flow element demonstrates knowledge transition between two neighbor intelligent system’s components. The corresponding knowledge flow formal descriptions based on these components' common knowledge format. The knowledge for intercomponent transferring allocated within flow's initial component memory. Appropriate knowledge format defines its structure.

Knowledge transferring uses knowledge structure morphism, based on saving the initial knowledge algebraic structure and replacement structures’ elements with elements adopted at transferring end components [8]. Such morphisms similar to knowledge translating between intelligent system architecture components. The simple case of such replacement consists in declaring identity for pairs of correspondent memory elements $\{q_1,...,q_n\}$ and $\{p_1,...,p_n\}$ for neighbor components. Knowledge for transferring into next flow component integrates content of operations ranges at current component's knowledge processing diagram. The transferred knowledge used then as distributed among operations domains' vertices within diagram. $SM_1 + SOSM_1$

3 Cross-Dimensional Intelligent Systems’ Knowledge Flows

Templates form basic description for realizing SA goals by knowledge flows and processing between and within intelligent system components $A1-C3$. Thoroughly developed templates and diagrams may settle the applied intelligent system complete model. The example of such model template for expert systems drawn below (see Fig. 9).

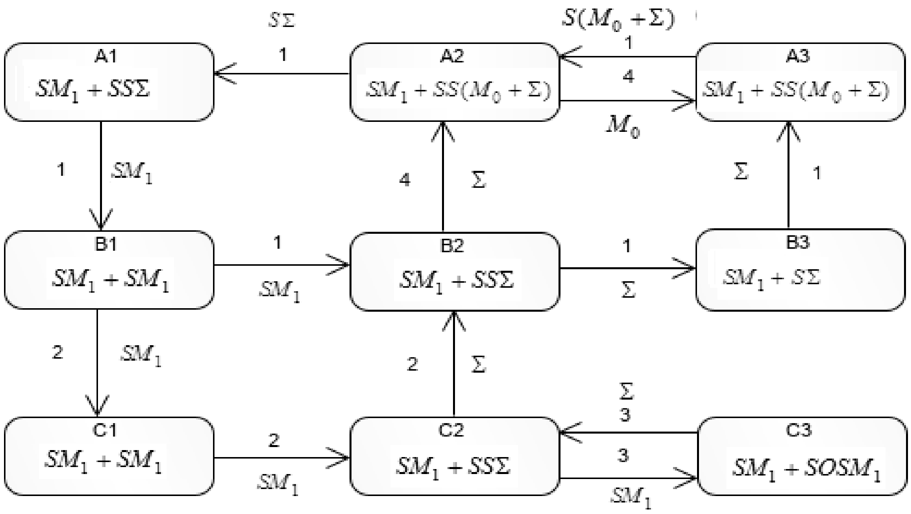

Fig. 9. Uniform knowledge flows templates for expert systems

Presented knowledge flows describe possible knowledge keeping and transferring formats within uniform expert systems' architecture. If A and B are operations' domains then their direct sum (direct production) expressed as $A+B$ (AB).

Four different paths present expert system's general lifecycles. The path with number 1 describes professional tasks' solving process as knowledge transferring cycle $A3$ - $A2$ - $A1$ - $B1$ - $B2$ - $B3$ - $A3$. Correspondent knowledge flow starts at $A3$ component. This component's memory structure looks as $SM_1 + SS(M_0 + \Sigma)$, where SM_1 – component's ontology (unordered set of simple knowledge), and $SS(M_0 + \Sigma)$ – set of sequences that accumulates unstructured knowledge sources with their properties descriptions represented by semantic hierarchies. Last sequences transferred separately into $A2$ component for their decomposition carrying out. Transferred knowledge general format is $SM_1 + SS(M_0 + \Sigma)$. The knowledge sources decompositions' structure has format $SS(M_0 + \Sigma)$. Such decompositions transferred into $A1$ for following complete decomposition by subject area E-ontology elements. These elements grouped into current situations' descriptions (SM_1) and transferred into $B1$ component. The SA-ontology applied for such description analysis t consists in professional goal recognizing and selecting necessary simple knowledge out of SA-ontology. The current situation has extended description (SM_1) and transferred into $B2$ component memory, where goal solving implemented as knowledge synthesis process. The current situation extended description (SM_1) transferred into $B2$ component memory, where selected goal implementing is realized as knowledge synthesis process called the knowledge evolution. Processes presented by sequences of synthesized knowledge structures ($SS\Sigma$). Goals implementations extracted off knowledge evolutions and transferred into component $B3$. Last component accumulate goals' processing results as system experience. The path's knowledge transfer performed between $B3$ and $A3$ components as synthesized goals implications of SA-ontology elements into their E-ontology equivalents (Σ). Transferred structure integrated into unstructured knowledge source and saved at $A3$ memory.

Others template paths ($2,3,4$) describe special knowledge flows. They extend knowledge-processing possibilities within goals' implementations. Path 2 ($B1$ - $C1$ - $C2$ - $B2$) added for goal implementation scenario synthesis. This knowledge flow starts with situation description (SM_1) transferring to $C1$. This description then extended by necessary cognitive goals and operations ontology elements at $C1$ component. Synthesized knowledge structure transferred into $C2$ for goal implementing scenario constructing. Next flow's step implements transfer into $B2$ as additional knowledge for path 1. Path 3 extends path 2 with new possibility of scenario selecting of $C3$ component's memory. The final path with number 4 proposed for modeling the knowledge flow for explanation the professional goals' synthesized implementation.

Explanation trace knowledge-processing sequence added by references on SA-ontology elements applied at knowledge structure that implements considered goal. These elements transferring from $B2$ to $A2$ consists in translating the SA–ontology elements by appropriate knowledge source elements and following synthesis explanation's unstructured representation ($A2 - A3$).

4 Final Results and Conclusions

The subject area's knowledge flows and processes concept integrates entities developed within a great number of knowledge areas that deal with human intelligence modeling. These systems' formal integration is possible by following the cybernetic principles as transdisciplinary approach to modeling living, social and technological systems by goals' driven information flows. The multi-dimension intelligent systems architecture allows such systems designing as structures created from unified components' universal set. Homomorphic extensions form base for templates and diagrams' multilevel modeling. *Time* and *grade* knowledge aspects extend number of intelligent systems' dimensions. The intelligent systems nearest exploration goals are 3-dimension architecture, operations domains (components memory) at semantic hierarchies' formats.

Acknowledgements

The reported study was funded by RFBR and administration of Krasnodar territory grant project number № 19-41-230008 and by RFBR grant project number № 20-01-00289.

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