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The Computational Psycholinguistic Situational-Fuzzy Self-Controlled Brain and Mind System under Uncertainty

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***Abstract*—**The modern Artificial Narrow Intelligence (ANI) models cannot: a) independently, situationally, and continuously function without of human intelligence, used for retraining and reprogramming the ANI's models, and b) think, understand, be conscious, and cognize under uncertainty and changing of the environmental objects. To eliminate these shortcomings and build a new generation of Artificial Intelligence systems, the paper proposes a Conception, Model, and Method of Computational Psycholinguistic Cognitive Situational-Fuzzy Self-Controlled Brain and Mind System (CPCSFSCBMSUU). This system uses a neural network as its computational memory, and activates functions of the perception, identification of real objects, fuzzy situational control, and forming images of these objects. These images and objects are used for modeling their psychological, linguistic, cognitive, and neural values of properties and features, the meanings of which are identified, interpreted, generated, and formed taking into account the identified subject area, using the data, information, knowledge, accumulated in the Memory. The functioning of the CPCSFSCBMSUU is carried out by its subsystems of the: fuzzy situational control of all processes, computational perception, identifying of reactions and actions, Psycholinguistic Cognitive Fuzzy Logical Inference, Decision Making, Reasoning, Systems Thinking, Planning, Awareness, Consciousness, Cognition, Intuition, and Wisdom. In doing so are performed analysis and processing of the psycholinguistic, subject, visual, signal, sound and other objects, accumulation and using the data, information and knowledge of the Memory, communication, and interaction with other computing systems, robots and humans in order of solving the joint tasks. To investigate the functional processes of the proposed system, the principles of situational control, fuzzy logic, psycholinguistics, informatics, and modern possibilities of data science were applied. The proposed self-controlled system of brain and mind is oriented on use as a plug-in in multilingual subject applications.

***Keywords*—**Computational psycholinguistic cognitive brain and mind system, situational fuzzy control, uncertainty, AI.

I. Introduction

THE research in the field of Computational Neuroscience is associated with the identification of the functions of the brain and the analysis of its behavior by influencing it. "The field of neurolinguistics focuses on the research of brain processes involved in the production and processing of natural language, including: processing of language sounds, encoding of word meanings, formation of complex sentences and more" [1]. To the question about "how close we are to understanding our own brain"? Christof Koch, Ph.D., Chief Scientist and President of the Allen Institute for Brain Science, expressed the following opinion: "We don't even understand the brain of a worm" [2]. Given the complexity of the structure, a huge number of relationships of elements of the brain, and not enough knowledge of how it functions, leads its researches to the need of modeling its supposed and plausible computational functional structure by applying a neural network. The functioning of the brain is aggravated by the current situation, the uncertainty and variability in time of its state and the state of environmental objects influencing it. In this regard, and according to our conducted researches [3]-[11] in the field of implementation of the Computational Brain (CB) and its Computational Mind (CM), there is a need to build a computational Concept, Model, and System of functioning of the CB on basis of applying of the main achievements of Psycholinguistics [12]-[14], Fuzzy Logic [15]-[21], Situational Control [22], Informatics [23], Data Science. These achievements have been applied in models of modeling memory, functionality and state of CPCSFSCBMSUU under uncertainty (Fig. 1). In doing so, the understanding of the environmental objects by the CB and its CM is a continuous process of cognition and response to ongoing events through of computational iterative psycholinguistic, cognitive and purposeful situational fuzzy control of the processes of Sensations, Imaginations, Perceptions, Analyses, Systems Thinking, Consciousness, Awareness, Decision Making, Representation, Generalization, and Explanation of Knowledge (Skills), Intuition, and Wisdom (application of Skills). These processes use, compare, and re-evaluate the accumulated and new knowledge, events, situations, states, that situationally change in time. The process of modeling is carried out through of CB and CM by revealing of the Imaginate Images of cognizable objects, their plausible assessments and attitudes, computation of their categories, properties, features, structures, and functions, related to the identified domain, current situation, and their uncertainty in the environment.

The topic of the CB is investigated in many scientific works [24]-[33]. However, [24] and [25] are of the greatest interest. Reference [24] represents "a computational system" of "a plausible brain architecture based on assemblies for implementing the syntactic processing of language in cortex", which "encompasses operations on assemblies of neurons", "by proposing a brain architecture for syntactic processing in the

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production of language", where "assemblies are large populations of neurons believed to imprint memories, concepts, words, and other cognitive information". In doing so, "the assemblies and their operations constitute a computational model of the brain".

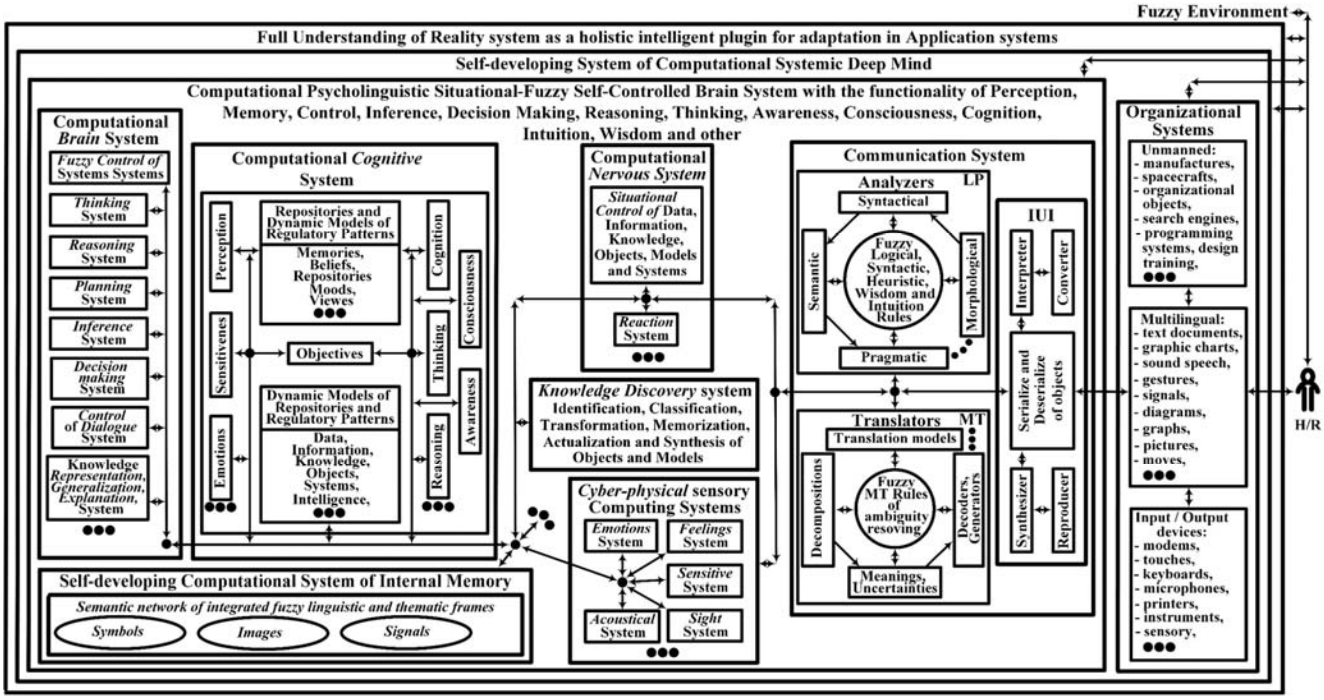

Fig. 1 Functioning Scheme of Computational Psycholinguistic Cognitive Situational-Fuzzy Self-Controlled Brain and Mind System under Uncertainty

Reference [25] explores a human "brain-like" computational model, which "works well on various environments with spares or dense obstacles" for "problem solving" "of the behavioral control in the primate brain" through of concentration "on the accumulative and overall performance of the brain subsystems, each of which is modeled by a computational system or a certain algorithm", using "a same working memory". In doing so, "the four parallel subsystems are different in many ways, such as the sensory inputs, computational power, model complexity, and so on".

The complexity of neural computing models, related to the behavior of the nervous system and other functions of the CB, leads to the creation of complex nonlinear mathematical equations, that are difficult to implement using modern Machine Learning, that mainly uses simple linear models of linear algebra, theory of probability and statistics. In this regard, we believe, that in order to investigate the complex (non-linear and dynamic) psycholinguistic, cognitive, and domain intellectual systems and their models, it is necessary to apply the principles of Fuzzy Logic [15]-[21] that allow to achieve for these systems and models the desired psycholinguistic and cognitive accuracy, and relevance by using the continuum values of fuzzy logic membership functions in the interval [0,1], as well as using the fuzzy values of the words, phrases of languages, and other heterogeneous values of objects of the reality.

Proceeding from the fact that the same phenomenon of the reality is perceived by different human ambiguously, based on their psycholinguistic and states of their cognitive models, and from that they see, hear, and assume, using their knowledge (experience) in the domain, we assume that the relevance computation by computer of each of these computational mental models and their corresponded computed mental validated states in the identified domain, generated by the CB, depend on the perceived by him of the relevant data, information, and knowledge about objects in the environment as a whole. Thus, the Psycholinguistic, Cognitive, and Domain perception of the environment's objects and the situational fuzzy control of the computation by the CB of the relationships, properties, categories, and features of these objects leads to the computational modeling of a plausible human Mind in the current situation (Fig. 2). In doing so, the computed and generated by CB the CM's Computational, Cognitive, and Domain Model (CPCDM) involves computing by the CB of the CM's Computational, Cognitive, and Domain State (CPCDS), using CB's computational subsystems of thinking, awareness, consciousness, cognition, inference, and others through their computational visual, auditory, olfactory, emotional, color, mental, behavioral, and other perceptions of changes in environmental objects in order to computation of the CM's generalized representations of the CPCDM and its CPCDS in surrounding reality. In comparison with CPCDM, the "mental models are personal, internal representation of external reality that people use to interact with the world around them" [26]. The CPCDM's and their CPCDS's representations (Fig. 2) are displayed in CB's and CM's Memory, and are implemented using their Structures, given in Figs. 3-5, Functional (Figs. 6-8), and Models (1), (2), (3), (4).

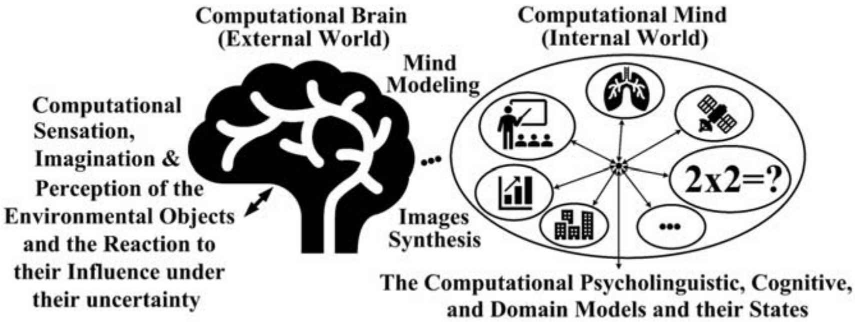

Fig. 2 The CB's producing of CM's Models and their States

	Domain model (P)					
	Language					
	Morphological model			Semantic model	Intelligent model	Psychological (mental) model
X (Corteges)	Lexis	Syntax	Grammar	Meanings Concepts	Knowledge	Mind: Knowledge, Knowledge, Knowledge
R (Relationships)	Categories	Categories	Categories			
	Properties	Properties	Properties			
	Terms	Terms	Terms			
	Values	Values	Values			

Fig. 3 The CB's and CM's Psycholinguistic, Cognitive, and Domain types of Data, Information and Knowledge

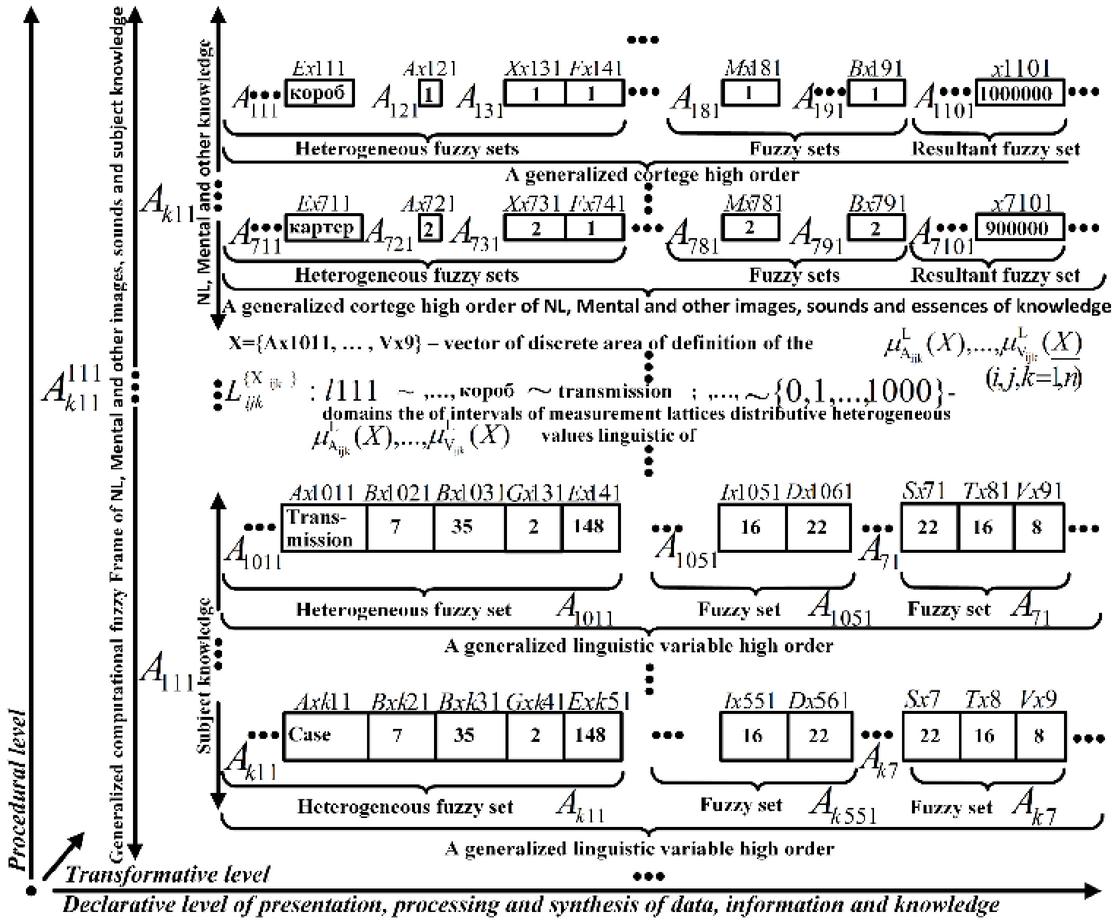

Fig. 4 The Structure of Computational Neural Network of Semantic Psycholinguistic Cognitive Fuzzy Frames of Domain's Data, Information and Knowledge in the Computing Brain's Memory

In the proposed article, we explore the functions, properties, and features of the proposed computational like-Brain, that is able to operate in conditions of uncertainty, changes in time of the own state and the state of the perceived objects, situations, and of the subject area in surrounding environment. To implement the mentioned functions and features of a plausible CPCSFSCBMSUU, in this article we proposed a Computational Psycholinguistic and Cognitive method of the perception and processing objects in the identified subject area under uncertainty. In doing so, the functionality of CPCSFSCBMSUU includes: a) Perception of the environmental objects, b) Generation of reactions and actions (Fig. 1), c) Computational Memory [3], d) Fuzzy Logical Inference [4], e) Decision Making [5], f) Planning [5], g) Situational Fuzzy Control [6] of all processes, h) Reasoning [7], i) Systems Thinking [7], j) Awareness [8], k) Consciousness [9], l) Cognition [10], m) Intuition, and Wisdom [11] in extreme situations, n) accumulation and using data, information, and knowledge [7]. The CPCSFSCBMSUU's properties and features include its capabilities of computational situational systemic functioning in conditions of uncertainty, changing situations in time, and the Situational Fuzzy Control [11] by all of the above-mentioned Computational Psycholinguistic Situational-Fuzzy Self-Controlled Brain and Mind subsystems. Consequently, in order to implement the functioning of the CPCSFSCBMSUU, it is necessary to provide the following: a) identify (perception of objects of reality) psycholinguistic (verbal and psychological), and cognitive properties and features, b) display them in the form of identified, structured, sorted, classified and digitized images of the subject area with storing them in computer memory in the form of a neural network, c) situationally generate and update the model for representing figurative knowledge in memory, d) build a functional model of a reasonable system using an actual memory model, and e) reasonably and situationally control the state of knowledge, and the functionality of the system in order to activate and update them under the conditions of uncertainty of objects and their environment in current and changing situation over time.

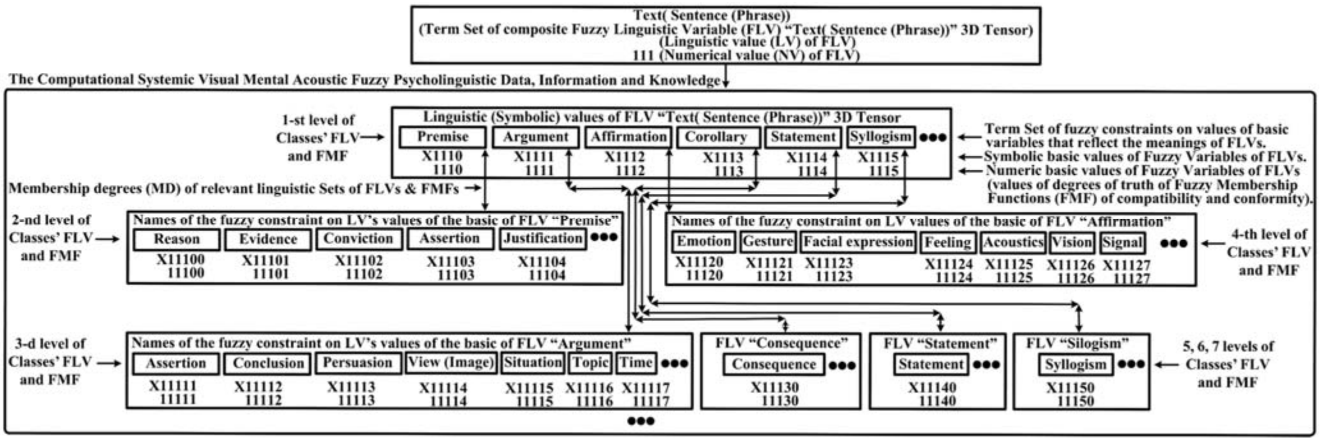

Fig. 5 The Generalized Neural Network Structure of Fuzzy Psycholinguistic, Cognitive, and Domain Objects in CB and CM Systems

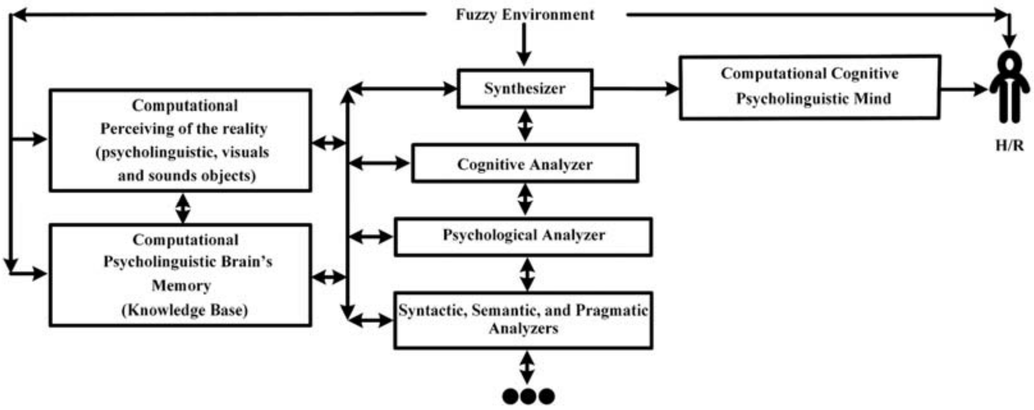

Fig. 6 The Scheme of Psycholinguistic Cognitive Analysis and Synthesis of the Mind in CB and CM Systems Synthesis in CB and CM systems

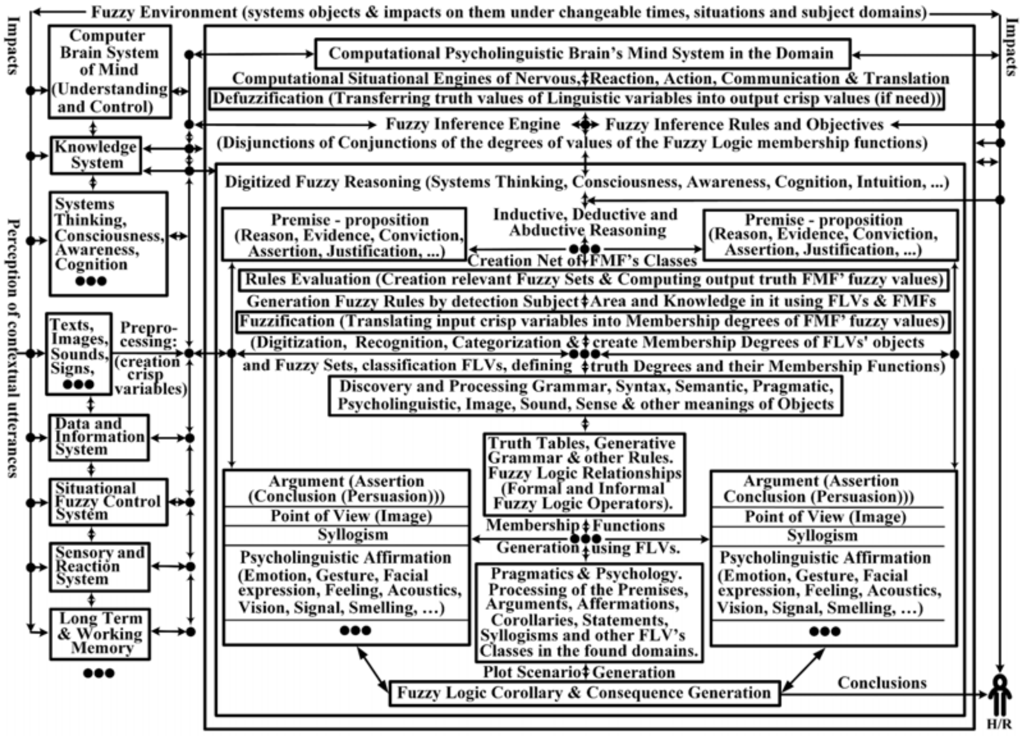

Fig. 7 The Functional Scheme of Psycholinguistic Cognitive Analysis and Synthesis of CM in Computing Brain and Mind System

II. The Memory Model of the Computational Psycholinguistic Situational-Fuzzy Self-Controlled Brain System

A. The Psycholinguistic Computational Cognitive Brain Memory Model

The psycholinguistic: a) categories, properties, features, and their fuzzy values (meanings), and b) structures of the CPCSFSCBMSUU's memory are presented, correspondently, in Figs. 3-5 [10]. They are organized in Memory in the form of a Neural Network of Semantic Fuzzy Frames, displaying the sets of languages used that are associated with psychological properties and features of the objects of subject area through of the relationships of their corresponding semantic and pragmatic meanings.

Fig. 4 is described in [10] and displays Fuzzy Logic's generated Linguistic Variables, Fuzzy Sets and their values (meanings, essences) for representing of the identified semantic fuzzy frames of Data, Information and Knowledge of the languages, visual, sound objects and their properties and features, that are saved in the CB's Memory.

B. The Synthesis of Brain's Functioning Results Using Its Memory Model

The analysis and synthesis of the CPCSFSCBMSUU's results are performed by using its functionality (Fig. 1) and the processes of obtaining the results are presented, respectively, in Figs. 6 and 7 by its psycholinguistic, cognitive, and domain Perceivers, Analyzers, and Synthesizers. The FLV and FMF (Figs. 5, 7), mean, respectively, the Fuzzy Linguistic Variable and Fuzzy Membership Function [15], [16], that had been applied for implementation of the CB's and CM's functionality (Fig. 8), by using of the models (1), (2), (3), (4) and of the generalized algorithms, presented on Figs. 6 and 7.

III. The Computational Psycholinguistic Cognitive Situational-Fuzzy Self-Controlled Brain's Model

A. The Model of Computational Situational Psycholinguistic Cognitive Fuzzy Control of the Computing Brain Processes

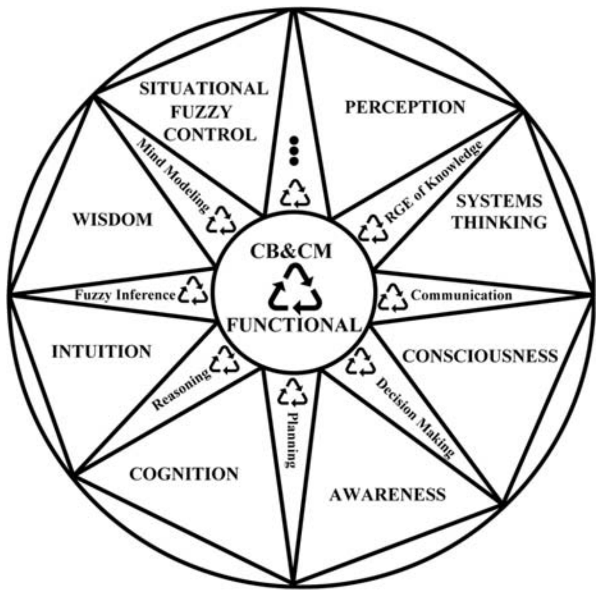

Fig. 8 The CB's and CM's Functionality

Model (1) is described in [10] and represents the model of Computational Situational Psycholinguistic Cognitive Fuzzy

Control of all CPCSFSCBMSUU's processes. Model (2) represents a set of CB's functional Psycholinguistic Cognitive processes, nested in each other, where each of them represents the value of the corresponding membership function of fuzzy logic [15], [16], computed by applying fuzzy matching rules, operations of Disjunction of Conjunctions, and modeling their relevant values using subject data, information, and knowledge, which is situationally identified through of the perception of lingual and subject objects from the surrounding reality. Equation (3) represents the model of Situational Control [22] in CPCSFSCBMSUU, which "determines the elementary act I_i of control in the process of modeling and selecting the relevant decision, that transforms the control system to the new situation S_i, which characterizes its new state Q_l, after the state Q_j has transitioned to Q_l" [10].

The components of the model (2) provide in CPCSFSCBMSUU the following psycholinguistic functionality [10] (Fig. 1): μ_R^Y – a cyber-physical module of CM, μ_R^F - a module of generation of the target of compositional rules and situational fuzzy control of actions of actualization, coordination of computational processes, μ_R^Z - a module of computational presentation, generalization and explanation of knowledge, μ_R^D - a module of computational fuzzy control of dialog and communication with users and systems, μ_R^M - a module of computational decision making and planning decisions, μ_R^T - a module of computational reasoning, $\mu_R^{\boldsymbol{H}}$ - a module of computational systems thinking, μ_R^C - a module of computational cognition, μ_R^O - a module of computational consciousness, μ_R^Z - a module of computational awareness, μ_R^H - a module of computational Intuition, μ_R^W - a module of computational Wisdom, μ_R^L - a module of computational Situational Fuzzy Inference.

$$\mu = < A_n^S, K_n^S, F_n^S, M_B^R(x), N_B^R(x) > \quad (1)$$

where:

$$M_B^R(x) = (\mu_R^Y(\mu_R^F(\mu_R^Z(\mu_R^D(\mu_R^M(\mu_R^T(\mu_R^H(\mu_R^C(\mu_R^O(\mu_R^Z(\mu_R^H(\mu_R^W(\mu_R^L)))))))))))) \quad (2)$$

$$N_B^R(x) = (S_i\!: Q_j \overset{x,u,w}{==>} Q_l\!:I_i) \quad (3)$$

where S_i – full, Q_j – current and Q_l – new situations of state of psycholinguistic, cognitive, and domain objects of data, information, knowledge in process of modeling of the CPCSFSCBMSUU, I_i - the generated CPCSFSCBMSUU's computing, psycholinguistic, and cognitive rules and actions, A_n^s – the Memory Model of the CPCSFSCBMSUU's computing, psycholinguistic, cognitive, and domain Data, Information and Knowledge (Figs. 3-5), K_n^s – the functional and processing model of the CPCSFSCBMSUU's computing, psycholinguistic, cognitive, and domain Data, Information and Knowledge (Figs. 4, 5), $M_B^R(X)$ – The model of modules of implementation CPCSFSCBMSUU's computing, psycholinguistic, cognitive, and domain functionalities (Fig. 1).

Equation (4) is a goal model, that implements the CPCSFSCBMSUU's target processes:

$$F_N^S = u(x, w) \quad (4)$$

where: x, w, and u – are, respectively, *definite, indefinite,* and *resultant* fuzzy self-controlled actions for implementing of the CPCSFSCBMSUU's processes, that situationally shifts its state from previous to the new state, relevant to the new situation.

IV. The Psycholinguistic Cognitive Situational-Fuzzy Self-Controlled Modeling of the CB's and CM's Functions

Since all the CPCSFSCBMSUU's functionalities of the modules, presented in model (1) are involved in the modeling of each of its functionality, therefore, the process and the model (1) of modeling of the CPCSFSCBMSUU are similar and unified for any functionality, mentioned in the model (1). Hence, Fig. 7, described in [10], is a modeling process of CPCSFSCBMSUU, using the mentioned *models* (1), (2), (3), (4), *measures* of opportunities (5), mapping *rules* (6), through of the CPCSFSCBMSUU's functionality (Fig. 7), where: α_n^{Poss}, β_n^{Poss} – are, respectively, the mappings, defined by generalized multidimensional matrices of psycholinguistic, cognitive, domain, and relevant numerical *estimates* (meanings) of fuzzy membership functions $\mu_b^q(X), \mu_a^q(X)$ and relationships R_b^X, R_a^X (Figs. 4, 5). A_n^s, $A_n'^s$ – are *current states* of the CPCSFSCBMSUU's models, respectively, before and after their actualization. B_n^s, $B_n'^s$ – are *mapped states* of the CPCSFSCBMSUU's models, respectively, before and after their actualization, related to the states A_n^s, $A_n'^s$. T, Q – are transformation operators of the CPCSFSCBMSUU's states, that shifts their *current* states A_n^s, B_n^s to their *new* states $B_n'^s$, $A_n'^s$.

The mapping *rules* (5) are described in [9] and they are used for mapping of the resultant values of Fuzzy Logic membership functions $\mu_{\boldsymbol{b}}^{\boldsymbol{q}}$ using their $\mu_{\boldsymbol{a}}^{\boldsymbol{q}}$ input values and *measures of opportunities* φ_l^q by *fuzzy matching* of fuzzy sets in the fuzzy *relations* R_b^X, R_a^X:

$$\mu_b^q(X) = \mu_a^q(X) \circ \varphi_l^q \quad (5)$$

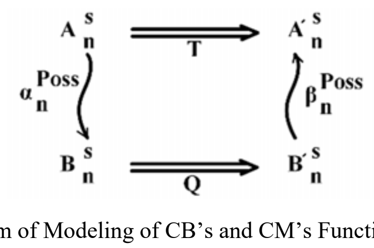

Fig. 9 Diagram of Modeling of CB's and CM's Functional Processes

Under the *fuzzy matching* of fuzzy sets, we mean the action, performed by functional procedures with the frame $\Phi_{L_{ijk}}^q : U_k^m \leftrightarrow V_k^l$ of the CPCSFSCBMSUU's Memory (Fig. 4), which generates the matching of base fuzzy sets U_k^m and V_k^l in CPCSFSCBMSUU. This matching of base fuzzy sets is implemented by using of compositional mapping rules $\mu_{B_{L_{ijk}}}^q(X) = \mu_{A_{L_{ijk}}}^q(X) \circ \Phi_{L_{ijk}}^q$, where: $\mu_{B_{L_{ijk}}}^q(X)$, $\mu_{A_{L_{ijk}}}^q(X)$ are, respectively, the *resultant* and *initial* CPCSFSCBMSUU's *membership functions* in the considered generalized fuzzy relation. $R_{ijk}^{X_{ijk}}$, $X = \{x_{ijk}\}$ is a vector of the discrete domain of definition of resultant and initial CPCSFSCBMSUU's membership functions, $\circ$ - is a *sign* of the computational mapping, $\Phi_{L_{ijk}}^{q}$ is a fuzzy *matching* in the procedure of CPCSFSCBMSUU, $A_{L_{ijk}}$, $B_{L_{ijk}}$ - are the heterogeneous multi-dimensional CPCSFSCBMSUU's *fuzzy sets*, L_{ijk} - are the heterogeneous distributive *lattices* of measurement intervals of the domains of definitions of considered membership functions, q – determine the *levels*, respectively, on *sublevels* of *modeling* of CPCSFSCBMSUU's Frames, l, k, m = (1, n).

The computational CPCSFSCBMSUU's *mapping rules* in model (6) are presented, described in [3], and used for modeling of the CPCSFSCBMSUU, where A, B are Fuzzy Sets.

The mapping rule (7), described in [3] represents one of the rules of the model (6), that applied by us in the CPCSFSCBMSUU.

$$M_B^R(X) = \vee(\wedge M_A^R(X)^\circ Pos\ a/a') \quad (6)$$

$$\text{IF } ((C'_{xyz} = L'_{xyz}) \text{ AND } C^*_{xyz} = R^*_{xyz})) \text{ THEN } ((C'_{xyz} = R'_{xyz}) \text{ AND } C^*_{xyz} = L^*_{xyz})) \quad (7)$$

Equation (7) represents an example of one of the psycholinguistic and cognitive mapping rules, that removes the multilingual semantic ambiguity, where the computational codes for identified word groups in multilingual text sentences, which presented in the Neural Network of PCSFSCBMSUU's Memory, means the following: C'_{xyz}, C^*_{xyz} - the *Conceptual compatibility* Codes of the words, respectively, for input and output languages; L'_{xyz}, L^*_{xyz} - the Codes of the words of *Left compatibilities* in relation to codes of words with *Conceptual compatibilities*, respectively, for the input and output languages; R'_{xyz}, R^*_{xyz} - codes of words of *Right compatibilities* in relation to codes of words with *Conceptual compatibilities*, respectively, for the input and output languages.

V. Conclusion

The main contribution and novelty of our proposed investigation, is to build a unique approach, model, method and system for the implementation of a computational fuzzy self-controlled situational psycholinguistic cognitive Brain and Mind System, that functions independently (without the use of human intelligence for retrain and reprogramming the system) in conditions of uncertainty, time changing of situations and objects in the surrounding reality, with using the *reasonable* functionality of the Computing Brain, with applying the main aspects of Fuzzy Logic, Psycholinguistics, Situational Control and modern Data Science and Informatics tools. The practical application of the proposed CPCSFSCBMSUU is oriented on using it as a software component in robotics, and devices, that requiring intelligence, self-control, and *reasonable* independent functioning under conditions of uncertainty. The proposed scientific contribution is focused on building the next-generation intelligent self-controlled Artificial Intelligence systems, with the possibilities of self-organization, self-adaptation, multilingual communication and helping people in conditions of uncertainty of the arisen situations.

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