Method for Evaluating the Hybrid Intelligent Multi-Agent System's Cohesion: Consistency of the Problem-Solving Protocol

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***Abstract*—The paper is aimed at developing of a new class of distributed artificial intelligence systems, namely, cohesive hybrid intelligent multi-agent systems. The concept of such systems was proposed in order to simplify the integration processes of heterogeneous intelligent agents created by various development teams. It is assumed that the agents of such systems should be able to independently agree on their goals, domain models and develop a problem-solving protocol. This paper presents one of the elements of the method for evaluating the cohesion of agents in the system, namely, evaluating the consistency of the problem-solving protocol.**

***Keywords*—cohesion, hybrid intelligent multi-agent system, team of specialists, protocol consistency**

I. INTRODUCTION

The impossibility of constructing an omniscient agent for solving practical problems, i.e. possessing all the necessary abilities, knowledge and resources to solve them [1], is one of the reasons for the emergence of the multi-agent approach to developing artificial intelligence systems. It assumes that an individual agent can have only a partial view of the general problem and is able to solve only some of its subproblems, and to tackle the problem as a whole it is necessary to organize their effective interaction.

Within the multi-agent approach, systems are developed to solve problems of varying degrees of modeling complexity [2], which is largely due to differences in approaches to the definition of the "agent" concept. In a weak sense, an agent is a software or hardware implemented system with the properties of autonomy, social behavior, reactivity, and proactivity [3], [4]. Stronger definitions of the "agent" concept imply endowing it with such anthropomorphic qualities as knowledge, beliefs, intentions, obligations and emotions [5]–[7]. This corresponds to the social aspect of solving practical problems in teams of specialists under the guidance of a decision maker. To model such teams, the concept of hybrid intelligent multi-agent systems (HIMAS) is proposed [2].

HIMAS is a hybrid intelligent system (HIS) [2], elements of which are realized as autonomous agents [1]. HIMAS, like HIS, integrate several artificial intelligence technologies to obtain problem-solving method overcoming disadvantages of its components and capable to solve problems with high modeling complexity [2]. Like in multi-agent systems (MAS), in HIMAS relations between agents and their environment are dynamically rebuilt depending of roles played by agents in certain conditions and interactions between them. Thus HIMAS combine the positive aspects of hybrid intelligent and multi-agent systems compensating their shortcomings such as lack of autonomy of HIS's elements and unclear specification of MAS's notion "agent": HIMAS have to contain heterogeneous intelligent agents with extensive domain models and goal-setting mechanisms, modelling the knowledge and reasoning of the relevant specialists "at a round table".

Traditionally, HIMAS were built by a single development team, and the agents had a common domain model, interaction protocol, and goals predetermined by the system developers. If agents are created by different independent development teams, a situation may arise when agents "speak" in different languages, use incompatible protocols, have conflicting goals and domain models, which requires additional labor costs to integrate them into a single system. To reduce labor costs for the integration of heterogeneous intelligent agents, it is proposed to implement mechanisms for modeling the processes of uniting a team of specialists within a new class of intelligent systems, namely cohesive hybrid intelligent multi-agent systems (CHIMAS) [8]. They will make it possible not only to synthesize a method for solving a problem over a heterogeneous model field [2]

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and to imitate the group work of specialists [1], but also to form a cohesive team of agents who understand each other and share common goals and norms.

II. GROUP COHESION IN TEAMS OF SPECIALISTS

Group mechanisms in small groups, and in particular in teams of specialists solving problems "at a round table", are studied within the group dynamics, i.e. the social psychology direction created by K. Levin [9]. Group dynamics studies social tension, aggression and discrimination, conflicts, leadership, psychological atmosphere, adaptation in a group, forming and deviation from group norms, group reaction, and others macro-level phenomena and processes in groups of people. One of important roles in group dynamics is played by researches on cohesion, which cover the processes of building of a single socio-psychological community in the group, and emergence of team's group properties preventing violation of its psychological integrity [10]. Studies of various group types, such as sport, business teams, military units and laboratory groups confirm the increase in work efficiency, the uniformity of the contribution of participants to the overall result and the stability of the group with increasing cohesion, when norms of the group behavior contribute to this [11]. Comprehensive reviews of the current state of group cohesion research are given in [12]–[16].

A. V. Petrovsky developed one of the most fundamental model in understanding the cohesion of groups and teams [17]. According to his stratometric concept (SC), cohesion of a small group of specialists consists of three layers (strata), representing three levels of group development:

- external level, at which emotional interpersonal relationships are investigated [10], [18]–[22];
- value-orientational unity (VOU), which considers the relations, mediated by joint activities that serve as the basis for formation of the basic values unity [10], [12], [17], [23]–[27];
- the core, which reveals the motives of the group members' choices of each other, mediated by common values that arise because members share the team goals [10], [16], [20], [21], [25], [28]–[33].

The similarity of goals, unity of opinions, points of view to the problem and group norms characterizing cohesion should be distinguished from the conformity, i.e. change in the behavior and attitudes of people aimed at promoting the actions and decisions of others [34]. Conformal behavior determines the appearance of a groupthink, i.e. a style of thinking when the desire for agreement among group members becomes more important than a realistic assessment of the situation and alternative solutions [35]. As shown in [36], the emergence of a groupthink strongly depends on the type of cohesion that exists in the group, and is typical mainly for groups with a high cohesion of the external level (the first stratum of the SC), due to emotional-interpersonal relationships. The groups with predominance of the cohesion of the second and third levels of the SC, called task cohesion in [36], show low levels of conformity and groupthink.

III. COHESIVE HYBRID INTELLIGENT MULTI-AGENT SYSTEM MODEL

Based on the HIMAS model [2], and taking into account SC, the CHIMAS model can be formulated as follows:

$$chimas =< AG, env, INT, ORG, \\ \{glng, ontng, protng\} >, \tag{1}$$

where AG is the set of agents, containing decision-making agent ag^{dm}, agents-specialists AG^{sp}, agent-facilitator ag^{fc} and other agents, presented in [8]; env is the model of the CHIMAS environment; INT is the set, described by expression (2), of the elements formalizing agents' interactions; ORG is the set of CHIMAS architectures; $\{glng$, $ontng$, $protng\}$ is the set of conceptual models of macro-level processes, where $glng$ is the model of the goal coordination by agents among themselves, ensuring cohesion at the core level of the SC; $ontng$ is the model of the agents' ontologies negotiation, corresponding to the exchange of knowledge, experience and beliefs between specialists and modeling of the VOU level of the SC; $protng$ is the model of a cohesive problem-solving protocol development by agents, which is relevant to the coordination of interaction norms at the VOU level of the SC. Due to the absence of an emotional component in CHIMAS agents, the stratum of emotional interpersonal relationships is not considered.

The set INT of elements for structuring the interactions of agents from formula (1) are described by the expression

$$INT = \{prot_{bsc}, PRC, LANG, ont_{bsc}, chn\}, \tag{2}$$

where $prot_{bsc}$ is the basic protocol that ensures the interaction of agents to form a cohesive interaction protocol to solve the problems posed to CHIMAS; PRC is the set of elements for constructing problem-solving protocol by agents-specialists and the decision-making agent; $LANG$ is the set of languages for coding agents' messages; ont_{bsc} is the basic ontology, described by expression (4), that provides agents' interpretation of the semantics of messages, when negotiating their ontologies (domain models), goals, and constructing a cohesive problem-solving protocol; chn is the degree of cohesion of agents, described by expression (6).

An agent $ag \in AG$ from formula (1) is described by the expression

$$ag =< id^{ag}, gl^{ag}, LANG^{ag}, ont^{ag}, ACT^{ag}, prot^{ag} >, \tag{3}$$

where id^{ag} is the agent identifier; gl^{ag} is the agent's fuzzy goal; $LANG^{ag} \subseteq LANG$ is the set of languages, messages in which can be read or written by the agent; ont^{ag} is the agent's ontology (domain model), described by the expression (4); ACT^{ag} is the set of actions implemented by the agent, among which for agents-specialists and the decision-making agent the goal negotiation act^{ag}_{glng}, the ontology negotiation act^{ag}_{ontng}, and the development of a cohesive problem-solving protocol act^{ag}_{protng} are distinguished, that is $\forall ag \in (AG^{sp} \cup \{ag^{dm}\})(\{act^{ag}_{glng}, act^{ag}_{ontng}, act^{ag}_{protng}\} \subset ACT^{ag})$; $prot^{ag}$ is the model of the problem-solving protocol, developed by the agent and described by expression (5).

The action $act^{ag} \in ACT^{ag}$ of an agent $ag \in AG$ is described by the expression

$$act^{ag} =< met^{ag}_{act}, it^{ag}_{act} >,$$

where met^{ag}_{act} is the method for solving the problem; it^{ag}_{act} is the intelligent technology, within which the method met^{ag}_{act} is implemented.

Thus, the CHIMAS function is described by the expressions

$$act_{chimas} = \left(\bigcup_{ag \in AG^*} ACT_{ag} \right) \cup act_{col},$$

$$\left| \bigcup_{ag \in AG} \bigcup_{act \in ACT^{ag}} it^{ag}_{act} \right| \geq 2,$$

where act_{col} is the collective function of CHIMAS, constructed by the agents dynamically in accordance with the developed problem-solving protocol; the condition requires that at least two intelligent technologies to be used [2].

The model of basic ontology ont_{bsc} from expression (2) and agent ontologies ont^{ag} from expression (3) are described by the expression [37]

$$ont =< L, C, R, AT, FC, FR, FA, H^c, H^r, INST >, \quad (4)$$

where $L = L^c \cup L^r \cup L^{at} \cup L^{va}$ is the lexicon, i.e. the set of lexemes consisting of subsets of lexemes denoting concepts L^c, relations L^r, attributes L^{at}, and their values L^{va}; C is the set of concepts; $R : \{C \times C\}$ is the set of relationships between concepts, the first component of the relationship tuple is called the domain $dm(r) = proj_1(r)$, and the second is the range of values $rn(r) = proj_2(r)$ of the relationship; $AT : C \times L^{va}$ is the set of concepts' attributes; $FC : 2^{L^c} \to 2^C$ is the function linking the lexicon with concepts; $FR : 2^{L^r} \to 2^R$ is the function linking the lexicon with relationships; $FA : L^{at} \to AT$ is the function linking the lexicon with attributes; $H^c = C \times C$ is the taxonomic hierarchy of concepts; $H^r = R \times R$ is the hierarchy of relations; $INST$ is the set of instances, each of which is a concept of a single volume or a "ground-level", specific element of a concept [38]. Functions FC and FR assume that, in general, one lexeme can correspond to several concepts or relationships, and, conversely, one concept or relationship can be described by several lexemes.

The protocol $prot^{ag}$ (3), constructed by agents from a set of elements PRC (2), defines a scheme (distributed algorithm) for the exchange of information, knowledge and coordination of agents [39]. It is described by the expression

$$prot^{ag} =< ROL, MTP, MRC, sch >, \quad (5)$$

where $ROL \subseteq C$ is the set of ontology concepts that describe the roles of agents; $MTP \subseteq C$ is the set of ontology concepts describing the types of messages transmitted by agents; MRC is the correspondence of pairs of agent roles and admissible types of messages for each pair; sch is the model of the message exchange scheme between pairs of agent roles, which determines the reaction of the agent playing the role to each type of messages, and their sequence.

When describing the message exchange scheme model sch from expression (5), the formalism of Petri nets is used [40]

$$pn =< PL, TR, IR >,$$

where $PL \subseteq C$ is the set of places; $TR \subseteq C$ is the set of transitions; $IR \subseteq (PL \times TR) \cup (TR \times PL)$ is the incidence relationship.

Messaging scheme is a multi-agent interaction protocol net (MIP-net), consisting of a set of synchronized Petri nets, which can be divided into two types: agent workflows net an (A-net) and interaction protocol net ipn (IP-net) [41]. A-net is a connected Petri net, in which there is a source-place, indicating the beginning of the process, and a sink-place, denoting the end of the process. IP-net is a Petri net, containing an input transition, before which there are no other elements of the network, a set of output transitions, after which there are no other elements of the network, as well as two disjoint subsets, the transitions of each of which are connected by synchronous communication elements $tr^{SC} \in TR^{SC}$ with transitions of the A-net, corresponding to the subset, based on multiple synchronization relationships R^{SC}.

Thus, the messaging scheme sch is a multi-agent interaction protocol network (MIP-net), defined by the following expression [41]:

$$sch^{ag} =< AN, IPN, TR^{SC}, R^{SC}, RAC, MRIPC >,$$

where $RAC \subseteq ROL \times AN$ is the mapping of the set of agent roles to the set of A-nets; $MRIPC \subseteq MRC \times IPN$ is the mapping of the correspondence of pairs of agent roles and admissible types of messages for each pair to a set of IP-nets.

IV. EVALUATING AGENT COHESION

The key characteristic describing the CHIMAS state is the degree of cohesion of its agents

$$chn =< gls, onts, protc >, gls, onts, protc \in [0, 1], \quad (6)$$

where gls is the degree of similarity of agents' goals; $onts$ is the degree of similarity of the agents' ontologies; $protc$ is the degree of consistency of the problem-solving protocol. It is used as an optimality criterion when negotiating goals act^{ag}_{glng} and ontologies act^{ag}_{ontng}, as well as developing a problem-solving protocol act^{ag}_{protng}. In addition, it is necessary when implementing the function of the agent-facilitator to analyze the current decision-making situation in CHIMAS.

The cohesion $chn^{ag}_{i\,j}$ of a pair of agents $ag_i, ag_j \in (AG^{sp} \cup \{ag^{dm}\})$ is evaluated by calculating the corresponding components of the tuple, that is $gls^{ag}_{i\,j}$, $onts^{ag}_{i\,j}$ and $protc^{ag}_{i\,j}$. The cohesion values of each pair of CHIMAS agents form a matrix $\mathbf{CHN}^{ag}$ of tuples defined in accordance with expression (6).

As a result, the cohesion of CHIMAS as a whole is described by the expression

$$chn_{chimas} = \sum_{i=1}^{nex+1} \sum_{j=1, j \neq i}^{nex+1} \frac{chn^{ag}_{i\,j}}{(nex+1)nex}.$$

The degree of cohesion of CHIMAS as a whole is necessary for the agent-facilitator to assess the current decision-making situation and to choose the methods of influencing the agent-specialists and the decision-making agent in order to increase the efficiency of their work. Agent-facilitator have to set up collective behavior methods, that increase cohesion, when agents are disunited, i.e. have incompatible goals, ontologies and problem-solving protocol models, and decrease it, when agents are too similar to prevent conformal behavior. For this, the agent-facilitator uses a fuzzy knowledge base about the required level of cohesion, depending on the characteristics of the problem, the stage of its solution and the assessment of the current situation in CHIMAS. The fuzzy knowledge base is developed based on the results of solving problems of various classes by CHIMAS.

The model gls for evaluating the degree of similarity of agents' goals is presented in [42]. The model $onts$ for evaluating the degree of similarity of agents' ontologies is considered in [43]. The model $protc$ for evaluating the degree of consistency of problem-solving protocols is considered in the following section.

V. EVALUATING PROBLEM-SOLVING PROTOCOL CONSISTENCY

To determine the similarity of problem-solving protocols, developed by different agents, it is required to calculate the similarity of each of the components of the tuple (5). For this purpose the measure of similarity of two concepts is introduced as the geometric mean of their lexicographic LSC (8) and taxonomic similarity TS (9)

$$S^C(c_k, c_m) = \sqrt{LSC(c_k, c_m)TS(c_k, c_m)}. \tag{7}$$

The lexicographic similarity of concepts LSC is determined by the expression

$$LSC(c_k, c_m) = LSL(FC^{-1}(c_k), FC^{-1}(c_m)), \tag{8}$$

where $FC^{-1} : C \to L^c$ is the function, inverse to FC, that establishes a correspondence between the concept and the lexeme describing it; LSL is the similarity of lexemes defined by the expression

$$LSL(l_k, l_m) = \max\left(0,\ 1 - \frac{ed(l_k, l_m)}{\min(|l_k|, |l_m|)}\right),$$

where ed is Levenshtein's editorial distance [44], defined as the number of characters that must be added, removed, or changed to make one lexeme from another.

To evaluate the taxonomic similarity TS of concepts, the measure is used, which is based on the upper cotopy, i.e. a set of vertices containing all the overlying vertices (superconcepts) in the taxonomic hierarchy H^{con} with respect to a given vertex and the vertex itself [45]

$$UC(c, H^c) = \{c_k \in C | H^c(c, c_k) \vee (c = c_k)\}.$$

The taxonomic measure of the concept similarity is the ratio of the number of common superconcepts of both vertices to the number of all superconcepts of both vertices

$$\begin{aligned} &TS(c_k, c_m, H^c_k, H^c_m) = \\ &= \frac{|FC^{-1}(UC(c_k, H^c_k)) \cap FC^{-1}(UC(c_m, H^c_m))|}{|FC^{-1}(UC(c_k, H^c_k)) \cup FC^{-1}(UC(c_m, H^c_m))|}. \end{aligned} \tag{9}$$

Thus, to evaluate the degree of similarity of the first components of the tuples, describing the problem-solving protocol (5), namely, the sets ROL^{ag}_i, ROL^{ag}_j of concepts-roles of agents, the correspondence, based on the measure of similarity of concepts (7), is established between the roles, used in the description of the protocol by each agent,

$$\begin{aligned} &MRL_{i\,j} = \{(u, v) | (u, v) \in ROL^{ag}_i \times ROL^{ag}_j \wedge \\ &\wedge v = \operatorname*{arg\,max}_{v' \in C_j} S^C(u, v') \wedge u = \operatorname*{arg\,max}_{u' \in C_i} S^C(u', v)\}. \end{aligned} \tag{10}$$

Based on the correspondence (10), the similarity of the sets of concept-roles is determined as follows

$$\begin{aligned} &ROLS(ROL^{ag}_i, ROL^{ag}_j) = \left|MRL^{-1}_{i\,j}\right| * \\ &* \sum_{mrl \in MRL_{i\,j}} S^C\left(proj_1(mrl),\ proj_2(mrl)\right). \end{aligned} \tag{11}$$

To evaluate the degree of similarity of the sets MTP^{ag}_i, MTP^{ag}_j of concept-types of messages the correspondence, based on the measure of similarity of concepts (7), is established between the types of messages used in the description of the protocol by each agent,

$$\begin{aligned} &MMT_{i\,j} = \{(u, v) | (u, v) \in MTP^{ag}_i \times MTP^{ag}_j \wedge \\ &\wedge v = \operatorname*{arg\,max}_{v' \in C_j} S^C(u, v') \wedge u = \operatorname*{arg\,max}_{u' \in C_i} S^C(u', v)\}. \end{aligned} \tag{12}$$

Based on the correspondence (12), the similarity of the sets of message types is determined as follows

$$\begin{aligned} &MTPS(MTP^{ag}_i, MTP^{ag}_j) = \left|MMT^{-1}_{i\,j}\right| * \\ &* \sum_{mmt \in MMT_{i\,j}} S^C\left(proj_1(mmt),\ proj_2(mmt)\right). \end{aligned} \tag{13}$$

When evaluating the degree of similarity of correspondences MRC^{ag}_i, MRC^{ag}_j between pairs of agents' roles and admissible types of messages for each pair, abbreviated correspondences are preliminarily formed between compatible pairs of roles and types of messages of both agents

$$\begin{aligned} &MRC^*_i = \{(t, u, v) | (t, u, v) \in MRC^{ag}_i \wedge \\ &\wedge t \in proj_1(MRL_{i\,j}) \wedge u \in proj_1(MRL_{i\,j}) \wedge \\ &\wedge v \in proj_1(MMT_{i\,j})\}, \end{aligned} \tag{14}$$

$$\begin{aligned} &MRC^*_j = \{(t, u, v) | (t, u, v) \in MRC^{ag}_j \wedge \\ &\wedge t \in proj_2(MRL_{i\,j}) \wedge u \in proj_2(MRL_{i\,j}) \wedge \\ &\wedge v \in proj_2(MMT_{i\,j})\}. \end{aligned} \tag{15}$$

On the basis of expressions (15), the degree of similarity of correspondences MRC^{ag}_i, MRC^{ag}_j between pairs of agents' roles and admissible types of messages for each pair is determined in accordance with the expression

$$MRCS(MRC^{ag}_i, MRC^{ag}_j) = \frac{\left|MRC^*_i \cap MRC^{**}_j\right|}{\left|MRC^*_i \cup MRC^{**}_j\right|}, \tag{16}$$

where MRC^{**}_j is the correspondence (15) expressed using the most similar concepts of the agent ag_i by the formula

$$\begin{aligned} MRC^{**}_j = \{&(MRL^{-1}_{i\,j}(t), MRL^{-1}_{i\,j}(u), MMT^{-1}_{i\,j}(v)) | \\ &(t, u, v) \in MRC^*_j\}. \end{aligned}$$

The calculation of the degree of similarity of the message exchange scheme is performed on the basis of the notion of the transition adjacency relation (TAR) [46]. The TAR in a Petri net defines a set TAR of ordered pairs $< tr_i, tr_j >$ of transitions that can be performed one after another. Suppose there are two Petri nets pn_i, pn_j of type A or IP, for which TARs TAR_i, TAR_j are constructed in accordance with the algorithm proposed in [47], then the similarity of two nets based on the measure of similarity of their TARs is determined by the expression

$$PS(pn_i, pn_j) = |TAR_i \cap TAR_j|\, |TAR_i \cup TAR_j|^{-1}. \tag{17}$$

Based on the similarity measure of Petri nets (17), the similarity of the message exchange schemes is calculated in accordance with the following expression

$$\begin{aligned} &SCHS(sch^{ag}_i, sch^{ag}_j) = \\ &= \Bigg(\left(|MRL_{i\,j}|\, |MRC^*_i|\, \left|MRC^*_j\right|\right)^{-1} * \\ &* \sum_{mrl \in MRL_{i\,j}} PS(proj_1(RAC_i(proj_1(mrl))), \\ &\quad proj_1(RAC_j(proj_2(mrl))))* \\ &* \sum_{mrc \in MRC^*_i} PS(proj_1(MRIPC_i(mrc)), \\ &\quad proj_1(MRIPC_j(F^{MRC}_{i\,j}(mrc))))* \\ &* \sum_{mrc \in MRC^*_j} PS(proj_1(MRIPC_i(F^{MRC}_{j\,i}(mrc)), \\ &\quad proj_1(MRIPC_j(mrc))) \Bigg)^{1/3}, \end{aligned} \tag{18}$$

where $F_{i\,j}^{MRC}$, $F_{j\,i}^{MRC}$ are the functions expressing the elements of correspondences (14) and (15) of each agent using the concepts of another agent, which are calculated in accordance with the following expressions

$$\begin{gathered} F_{i\,j}^{MRC}(mrc_i^*) = (MRL_{i\,j}(proj_1(mrc_i^*)), \\ MRL_{i\,j}(proj_2(mrc_i^*)), MMT_{i\,j}(proj_3(mrc_i^*))), \\ F_{j\,i}^{MRC}(mrc_j^*) = (MRL_{i\,j}^{-1}(proj_1(mrc_j^*)), \\ MRL_{i\,j}^{-1}(proj_2(mrc_j^*)), MMT_{i\,j}^{-1}(proj_3(mrc_j^*))). \end{gathered}$$

As a result, the consistency of the problem-solving protocols developed by each of the agents is determined based on expressions (11), (13), (16), and (18) as the geometric mean of the consistency of each of the components of the tuple (5)

$$\begin{gathered} prots_{i\,j}^{ag} = \big(ROLS(prot_i^{ag}, prot_j^{ag})MTPS(prot_i^{ag}, prot_j^{ag})* \\ *MRCS(prot_i^{ag}, prot_j^{ag})SCHS(prot_i^{ag}, prot_j^{ag})\big)^{0.25}. \end{gathered}$$

Thus, the calculated value of the consistency of the problem-solving protocols together with the values of the similarity of goals [42] and agent ontologies [43] form the value of the cohesion vector of agent pair (6). It is used both by agents-specialists to estimate the interaction effectiveness, and by the agent-facilitator to assess the problem-solving situation in CHIMAS. Thanks to the elements of cohesion modeling in the intelligent system, the behavior of agents is provided, which allows to overcome disagreements and avoid conflicts caused by differences in the models of the problem and the goals of its solution. As a result, by analogy with the team of specialists, CHIMAS dynamically develops a relevant solution method every time a problem is solved. Testing of CHIMAS methods is planned to be carried out on the example of the problem of planning the restoration of the power supply system [48].

VI. CONCLUSION

The paper substantiates the need to model cohesion processes in intelligent systems in order to reduce labor costs when integrating agents created by various teams of developers. The CHIMAS model is presented, the agents of which have mechanisms for independent, without the intervention of the system developers or its users, agreeing the goals and ontologies, as well as developing problem-solving protocol. The method for evaluating cohesion and, in particular, the detailed description of one of its parts, namely the evaluation of the consistency of problem-solving protocols developed by the agents is presented. This method makes it possible to model the cohesion of the team at two of the three levels of the stratometric concept of A.V. Petrovsky, simulating the convergence of goals, the exchange of knowledge and the development of common norms of behavior without conformity, which allows CHIMAS to more relevantly model the processes of solving problems by long-existing teams of specialists.

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Метод оценки сплоченности гибридной интеллектуальной многоагентной системы: согласованность протокола решения проблемы

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Работа направлена на построение нового класса систем распределенного искусственного интеллекта, а именно сплоченных гибридных интеллектуальных многоагентных систем. Концепция таких систем была предложена, чтобы упростить процессы интеграции разнородных интеллектуальных агентов, созданных различными коллективами разработчиков. Предполагается, что агенты таких систем должны быть способны самостоятельно согласовывать свои цели, модели предметной области и вырабатывать протокол решения поставленной проблемы. В настоящей статье представлен один из элементов метода оценки сплоченности агентов системы, а именно оценка согласованности протокола решения проблемы.

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