Cohesive Hybrid Intelligent Multi-Agent System Architecture

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***Abstract*—The paper is devoted to the development of architecture of a new class of intelligent system, namely a cohesive hybrid intelligent multi-agent system. This intelligent system is designed to model collective problem solving by an expert team at round-table. Like traditional hybrid intelligent multi-agent systems, this system integrates the advantages of the hybrid intelligent system concept and the multi-agent approach. The key difference of the proposed class of intelligent systems is the modeling of expert team cohesion, by coordinating goals, domain models and developing problem-solving protocol by agents. These mechanisms are especially relevant when a hybrid intelligent multi-agent system is built from agents developed by various independent teams. The paper presents the model of cohesive hybrid intelligent multi-agent system, its functional structure, and the architectures of its agents.**

I. Introduction

As shown by A.S. Narinyany, problems that arise in decision-making practice are characterized by many non-factors: heterogeneity, underdetermination, inaccuracy, fuzziness, incompleteness and others [1]. V.F. Spiridonov characterizes the concept "problem" by weak formalization, complex structure, network nature of conditions and goals, opacity (uncertainty), as well as subjectivity and dynamism [2]. A practical study of the problems arising in the management of transport logistics, electric power, medicine, and other areas has shown the relevance of these estimates [3–5]. When developing intelligent systems for such conditions, successful practices for solving problems used in decision-maker guided expert groups should be modeled. The success of such groups depends on many factors: the professionalism of the participants, their goals, the effectiveness of communication and management, the fair distribution of responsibilities and resources, the organization of the process of collective problem solving and others. In many respects, the success of groups’ work depends on the ability of the leader (formal or informal) to create a team from the small group of individualistic experts, that is, an association of people sharing common goal, characterized by the integrity, the organization inherent to it, the distribution of functions, the structure of leadership and management.

The issues of integrating the knowledge and reasoning of a small group of experts under the guidance of a decision-maker are investigated in the researches on hybrid intelligent multi-agent systems (HIMAS). HIMAS are the hybrid intelligent systems (HIS) that implement a multi-agent approach [4]. Elements of such HIS are implemented in the form of autonomous agents [6-8]. Like multi-agent systems (MAS), they model the interactions of autonomous agents with each other and with the external environment, because of which the system architecture can be dynamically rebuilt in accordance with the specific functions (roles) of the agents and established relationships between them. As a result, HIMAS combine the positive aspects of HIS and MAS. Due to the combination of several methods of artificial intelligence, they are relevant to problems with high modeling complexity [4]. By simulating the interaction of experts and the resulting collective processes, they are able to change their architecture to achieve a synergistic effect, i.e. finding better solutions than agents working separately [4].

However, a significant aspect fell out of sight of the HIMAS developers, namely the formation of a cohesive team of agents, which is especially relevant when creating agents by various autonomous developers. In this case, agents should not only “speak” the same language and be compatible with the basic protocols implemented in the system, but also have mechanisms to ensure their integration into a single team. System’s agents should exchange information about their goals, interests, knowledge, experience with each other, develop and coordinate common goals, values, norms, means and methods of activity for the system, as well as internalize them. In this regard, the modeling of group cohesion of expert team by means of a new class of HIMAS, namely cohesive hybrid intelligent multi-agent systems (CHIMAS) is relevant.

II. Group cohesion of expert teams

When forming expert team to solve the practical problem, it is not enough to select them solely according to functional requirements: the group runs the risk of not agreeing, becoming mired in conflicts or, being too carried away by the details, and not solving the problem as a whole in the specified time [9]. A set of knowledge, skills and abilities does not guarantee a solution to the problem, and issues of communication, psychological compatibility, conflict, cohesion, i.e. group rather than individual mechanisms become more important. Such mechanisms are studied in the framework of one of the areas of social psychology, namely group dynamics [10]. In the framework of research on group dynamics, one of the leading places is occupied by studies of group cohesion. Group cohesion is in the creation of a single socio-psychological community of group members, and involves the emergence of a system of group properties that impede the violation of its psychological integrity [11]. The phenomenon of group cohesion increases the satisfaction of participants from group work, the intensity of interaction between them, as well as the productivity of the group as a whole. Group cohesion is a measure of the interconnectedness of team members, which is determined by the degrees of positivity and intensity of emotional interpersonal relationships of everyone with everyone, the coincidence of orientations on the basic values relating to the process of joint activity, as well as the sharing of the group's goals [9].

L. Festinger investigated the phenomenon of group cohesion based on the frequency and strength of communicative relations [12]. He defined cohesion as the sum of all the forces holding members within group, for example, the attractiveness of a group for an individual or satisfaction with membership in it. The followers of L. Festinger introduced the concepts of reward (satisfaction of bio-needs, safety, acceptance by other participants, and support for self-esteem) and losses (time and effort to interact with unpleasant partners, criticism or rejection by partners, etc.). D. Cartwright argued that cohesion depends not only on the goals and characteristics of the group, but also on their relationship with the needs of the group members, expectations of "favorable membership" [13]. B.P. Indik, P. Sagi and P. Olmsted as the main factor of cohesion highlighted the personal involvement of the individual in the group, the emergence of a sense of complicity with it [14, 15]. According to the research of S. Kratochvil, the group cohesion contributes to the following factors: the satisfaction of the individual needs of the group member; the group goals that are consistent with individual needs; interdependence when working on specific tasks; benefits of group membership; sympathy between group members; friendly, welcoming atmosphere; the prestige of the group that increase member's prestige; the impact of group activities; competition with another group, etc. [16].

Within the cognitive-oriented approach, the most important condition of the group cohesion is the similarity in opinions, attitudes, and values of group members. One of the first researchers of this approach was T. Newcomb [17], who singled out the concept of "consent" that is the existence of similar orientations between two or more persons. D. Byrne also conducted a study of the relationship between similarities in attitudes and group attractiveness [18]. He established that there is a linear relationship between these phenomena. In the work of A. Harrison and M. Connors the degree of cohesion is depend on the productivity of the group [19].

The stratometric concept of A.V. Petrovsky [20] has become the fundamental model in understanding the cohesion of groups and teams. According to it the cohesion of a group is considered at three levels (strata):

1) external level (emotional interpersonal relationships);
2) value-orient unity (relations are mediated by joint activity, on the basis of which unity of basic values arises);
3) core (group members share the goals of group activity, thus motives for choosing each other by the group members can be revealed here, which, in turn, can be mediated by common values: attitude to the world, society, work).

Three layers of group structures at the same time can be considered as three levels of development of a group, including three levels of group cohesion. In order to study the dependence of the team's effectiveness on the degree of cohesion, as well as the influence of the norms of group behavior on team cohesion, it is proposed to perform computer modeling of the cohesion effect using HIMAS [4].

III. MODEL OF THE COHESIVE HYBRID INTELLIGENT MULTI-AGENT SYSTEM

The development of an agent model that acts in accordance with its own goal and domain model, and not the goal and domain model of the system as a whole is the necessary condition for the implementation of CHIMAS in accordance with the stratometric concept of A.V. Petrovsky. Due to the lack of an emotional component in agents used to model expert teams, the stratum of emotional interpersonal relationships is not considered. Thus, cohesion in CHIMAS is modeled at two of the three levels proposed by A.V. Petrovsky:

1) the core level by coordinating the goals of agents among themselves;
2) the level of value-oriented unity by coordinating domain models, which corresponds to the exchange of knowledge, experience and beliefs between experts, and forming cohesive protocol for solving the problem, which ensures coordination of interaction standards.

Thus, based on the HIMAS model proposed in [4], the CHIMAS model can be formulated as follows:

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

where AG is the set of agents described by expression (2); env is a conceptual model of the external environment of CHIMAS; INT is the set of elements of structuring agent interactions described by expression (3); ORG is a set of architectures of CHIMAS; $\{glng, ontng, protng\}$ is the set of conceptual models of macro-level processes in CHIMAS: $glng$ is a model of the process of coordinating the goals of agents among themselves; $ontng$ is a model of the process of coordinating models of the subject area of agents; $protng$ is a model of the process of formation of a cohesive interaction protocol by agents.

The set of agents from (1) is described by the expression

$$\begin{aligned} AG = \{ag^{dm},\ ag^{fc},\ ag^{med},\ ag^{int},\ ag^{pc}\} \cup \\ \cup AG^{ex} \cup AG^{tr} \cup AG^{it}, \end{aligned} \quad (2)$$

where ag^{dm} is the decision-making agent; ag^{fc} is the agent-facilitator; ag^{med} is the intermediary agent; ag^{int} is the interface agent; ag^{pc} is the protocol control agent; $AG^{ex} = \{ag_1^{ex}, ..., ag_{nex}^{ex}\}$ is the subset of expert agents, where nex is the number of expert agents; $AG^{tr} = \{ag_1^{tr}, ..., ag_{ntr}^{tr}\}$ is the subset of translation agents, where ntr is the number of translation agents; $AG^{it} = \{ag_{an}^{it}, ag_{st}^{it}, ag_{lo}^{it}, ag_{fu}^{it}, ag_{sy}^{it}, ag_{cnv}^{it}\}$ is the subset of intelligent technology agents, where ag_{an}^{it} is the analytical agent, ag_{st}^{it} is the stochastic agent, ag_{lo}^{it} is the logical agent, ag_{fu}^{it} is the fuzzy agent, ag_{sy}^{it} is the symbolic agent, ag_{cnv}^{it} is the agent-converter.

Elements for structuring interactions of agents from formula (1) are described by the expression

$$INT = \{prot_{bsc}, PRC, LANG, ont_{bsc}\}, \quad (3)$$

where $prot_{bsc}$ is the basic protocol that ensures the interaction of agents for the formation of cohesive interaction protocol to solve the problems posed to CHIMAS; PRC is the set of elements for constructing cohesive problem-solving protocol by expert agents, and the decision-making agent; $LANG$ is the set of message transfer languages that are used by CHIMAS agents; ont_{bsc} is a basic ontology common to all CHIMAS agents that provides agents with an understanding of the meaning of the messages transmitted by coordinating their own domain models, goals, and forming cohesive problem-solving protocol.

The agent $ag \in AG$ from formula (2) is described by the expression

$$ag = < id^{ag}, gl^{ag}, LANG^{ag}, ont^{ag}, ACT^{ag} >,$$

where id^{ag} is the agent identifier; gl^{ag} is the agent's goal; $LANG^{ag} \subseteq LANG$ is the set of messaging languages; ont^{ag} is the agent domain model; ACT^{ag} is the set of actions carried out by the agent, among which for expert agents, and the decision-making agent there are the coordination of goals act_{glng}^{ag}, the coordination of domain models act_{ontng}^{ag}, the development of the problem-solving protocol act_{protng}^{ag}, that is $\forall ag \in (AG^{ex} \cup \{ag^{dm}\})\ (\{act_{glng}^{ag}, act_{ontng}^{ag}, act_{protng}^{ag}\} \subset ACT^{ag})$.

The action of an agent from the set ACT^{ag} is described by the expression

$$act^{ag} = < met_{act}^{ag}, it_{act}^{ag} >,$$

where met_{ag} is the method of solving the problem; it_{ag} is the intelligent technology within which the method met_{ag} is implemented.

Thus, the CHIMAS function is described by the expression

$$act_{chimas} = (\bigcup_{ag \in AG^*} ACT_{ag}) \cup act_{col}, \quad \left| \bigcup_{ag \in AG} \bigcup_{act \in ACT^{ag}} it_{act}^{ag} \right| ..2,$$

where act_{col} is the collective function of CHIMAS, designed by agents dynamically in accordance with the developed problem-solving protocol; the imposed restriction requires that at least two intelligent technologies [4] have to be used as part of the CHIMAS.

IV. Functional Structure of the Cohesive Hybrid Intelligent Multi-Agent System

For computer modeling of group cohesion of expert team, the functional structure of CHIMAS in Fig. 1 is proposed. Four subsystems are distinguished in CHIMAS structure: interface, hybridization, problem-solving, and management.

The interface subsystem consists of a single agent. The interface agent is responsible for interacting with the user: it requests input data and gives the result, as well as visualizes the processes in CHIMAS, in particular, the dynamics of agent cohesion, development of problem-solving protocol, coordination of goals and domain models by agents of the problem-solving subsystem. It does not participate in the coordination of goals and domain models of agents of the problem-solving subsystem, as well as in the development of the cohesive problem-solving protocol, but monitors these processes and visualizes them to the user.

The management subsystem contains the basic ontology, set of translation agents, the intermediary agent, the agent-facilitator, and the protocol control agent. The basic ontology is the semantic network, the basis of agent interaction, which corresponds ont_{bsc} element from formula (3). Translation agents are designed to translate agents' messages from one language to another. The need for such agents is due to the fact that CHIMAS agents can be created by different teams of developers and use different languages for transmitting messages from the set $LANG$, while they are able to communicate with each other directly only if the intersection of the sets of languages that they "speak" is not empty. Otherwise, they need to use the services of translation agents. The intermediary agent tracks the names, models, and capabilities of registered agents. The agent-facilitator is responsible for organizing the effective teamwork of the agents. It identifies the stages of the problem-solving process, the composition of expert agents, the coordination of their goals, domain models, the current situation in the CHIMAS, the positive and negative group effects that arise, affects the expert agents to activate negotiation processes to coordinate goals, domain models or adjust problem-solving protocol. The protocol control agent captures changes to the problem-solving protocol that are made by the agents of the problem solution subsystem, and monitors its compliance.

The hybridization subsystem is represented by the analytical, logical, symbolic, stochastic and fuzzy agents, which, together with the agent-converter, implement the hybrid component of CHIMAS, combining diverse knowledge. They provide "services" to agents using the following models and algorithms: algebraic equations for describing cause-effect relationships domain concepts; Monte Carlo method; production expert system with forward-looking reasoning; the fuzzy inference algorithm of Mamdani and others.

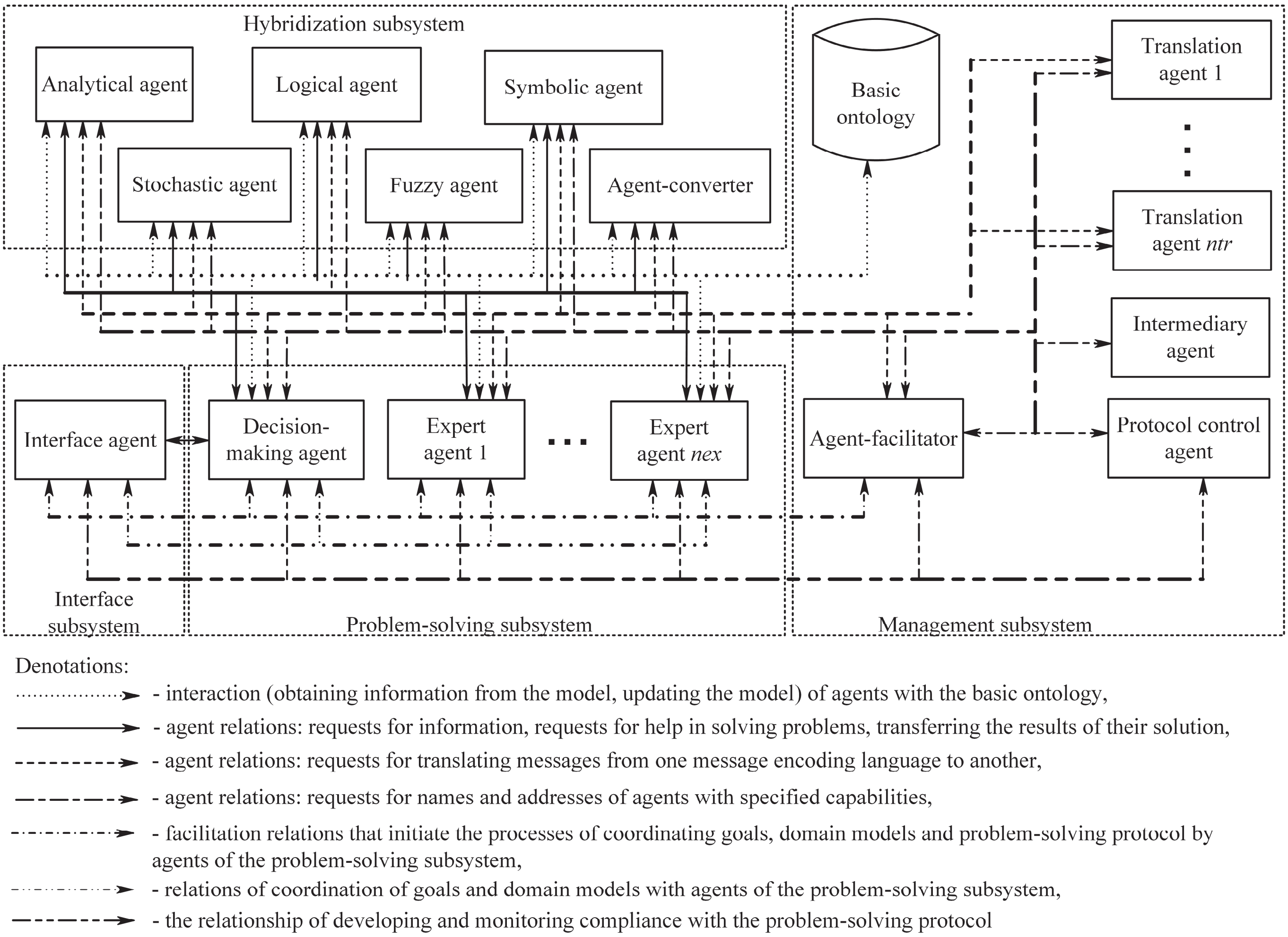

Fig. 1. Functional structure of the cohesive hybrid intelligent multi-agent system

The agents of the hybridization subsystem are reflexive, that is, they do not have a developed model of the subject area or goal setting, and fulfill the instructions of other agents in accordance with the laid down algorithms; they are similar to objects in the paradigm of object-oriented programming.

Agents of the problem-solving subsystem model the reasoning of expert team under the guidance of the decision maker at round table to solve a problem. The decision-making agent models the work of the decision-maker: sets tasks to expert agents, collects work results, determines whether the stopping criterion is reached, and either makes the final decision or starts a new iteration of the problem-solving process. Expert agents model expert reasoning and, using their own domain models and problem-solving algorithms, generate particular solutions of sub-problems or alternative solutions to the problem, depending on the task assigned to them by the decision-making agent.

Different teams of developers can create agents of the problem-solving subsystem in the general case; therefore, their domain models and goals can differ and even contradict each other. In this regard, to solve the problems effectively, the agents of the problem-solving subsystem have to coordinate their domain models, goals, and develop the problem-solving protocol at the request of the agent-facilitator. Moreover, they do not strictly obey him, but “agree” among themselves. The interface agent monitors these processes and displays them to the user.

V. Agent architectures

The interface agent architecture is shown in Fig. 2. The CHIMAS message router is not part of the agent, but is a messaging subsystem of the software platform on which the CHIMAS is implemented, providing message delivery between agents. The message receiving/sending subsystem allows the agent to interact with other agents, recording messages in a language from the set $LANG^{ag}$, for example, KQML or ACL. The basic ontology interpreter provides message generation using the CHIMAS basic ontology (Fig. 1), analyses the semantics of the body of parsed messages from message receiving/sending subsystem, generates program objects based on message body and CHIMAS basic ontology, and then routes them to the proper subsystem according to the message type and content. This subsystem is typical for the CHIMAS agent, and when considering the architectures of other agents, it is omitted. If the basic ontology interpreter cannot determine the semantics of the received message, it is transmitted for analysis to the ontology interpreter of the problem domain. The problem domain ontology of the interface agent is synchronized with the corresponding ontology of the decision-making agent. The input / output subsystem provides user interaction, requests input data, reports the result, provides the ability to edit the database, visualize group processes in CHIMAS with methods from the base of visualization methods. The database of posed problem's objects stores information about resources, actions and their properties, determining the conditions of the problem to be solved. For example, in case of problem of differential diagnostic of disease this database stores personal patient data, laboratory and functional studies, etc.

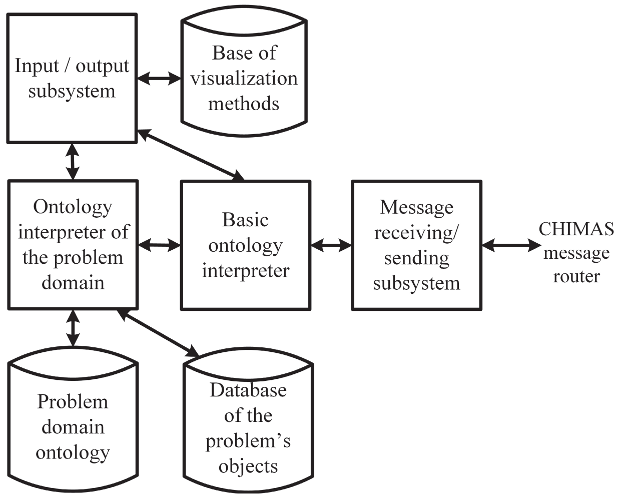

Fig. 2. The interface agent architecture

The architecture of an intelligent technology agent, i.e. an agent of hybridization subsystem, is shown in Fig. 3. Algorithms of intelligent technology implement the corresponding problem-solving methods: algebraic equations; Monte Carlo method; production expert system; Mamdani fuzzy inference algorithm etc. It solves tasks transmitted by expert agents and other intelligent technology agents.

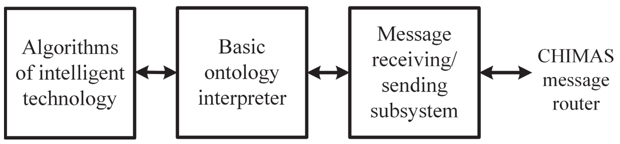

Fig. 3. The architecture of an intelligent technology agent

The architecture of a translation agent is presented in Fig. 4. Translation algorithms implement procedures for translating messages from one language $lang_i$ to another $lang_j$, $lang_i, lang_j \in LANG^{ag} \subseteq LANG$.

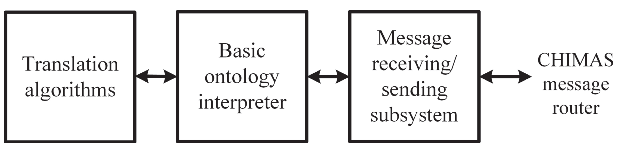

Fig. 4. The architecture of a translation agent

The architecture of the intermediary agent is presented in Fig. 5. The database management subsystem adds, deletes, modifies and searches for agent records in the database (list) of agents. The agent database stores in the form of records information about registered agents and their capabilities.

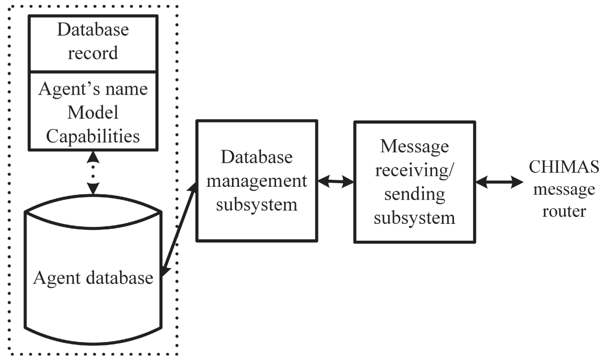

Fig. 5. The architecture of the intermediary agent

The architecture of the protocol control agent is presented in Fig. 6. Problem-solving protocol model stores the snapshot of the agreements of the problem-solving subsystem's agents about cohesive problem-solving protocol. Protocol adjustment subsystem monitors messages associated with the development and modification of the cohesive problem-solving protocol, and captures these changes in the protocol model. Monitoring of the protocol compliance subsystem traces all messages that expert agents and decision-making agent send during problem solving and verifies their compliance with the protocol. If this subsystem detects a protocol violation, it initiates the sending of the appropriate message to the agent-facilitator and interface agent through the basic ontology interpreter and the message receiving/sending subsystem.

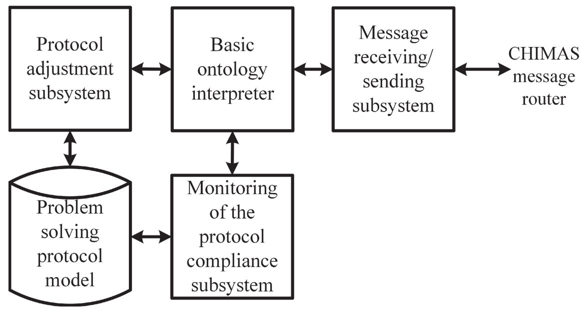

Fig. 6. The architecture of the protocol control agent

The architecture of the agent-facilitator is shown in Fig. 7. The subsystem for analyzing the situation of collective problem solving performs the identification of the current stage of the problem-solving process taking into account degrees of coherence of agent's goals and problem domain ontology as well as the existence of the cohesive problem-solving protocol and its possible violations. The subsystem for choosing of impact method using fuzzy knowledge base imitates the work of a facilitator in choosing the means for activating teamwork and resolving conflicts of the expert team that is relevant to the collective problem-solving situation. The fuzzy knowledge base of methods' relevance describes the rules for choosing the method to impact agents of problem-solving subsystem depending on the decision-making situations in the CHIMAS, as well as various features of the problems. To form such a base, it is necessary to complete a series of computational experiments and establish a correspondence between the class of problem and the relevant methods.

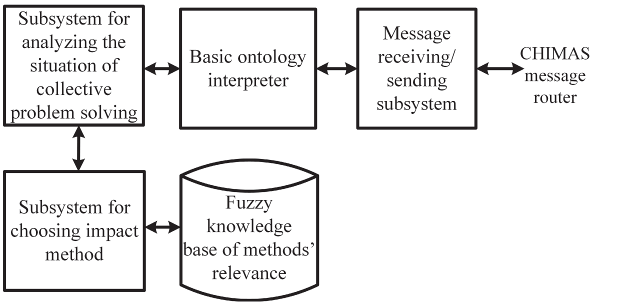

Fig. 7. The architecture of the agent-facilitator

The architecture of the expert agent is shown in Fig. 8. The ontology interpreter of the problem domain, depending on the content of the received message, starts one of the following algorithms: problem-solving algorithm using algorithm interpreter; goal adjustment algorithm; belief adjustment algorithm; problem-solving protocol adjustment algorithm; problem domain adjustment algorithm. Following data can be transferred as arguments to the launched algorithm: the contents of the received message in a structured form; information about the agent's goal; its beliefs; model of the problem; model of the problem-solving protocol. The base of problem-solving algorithms stores a set of algorithms that the expert agent performs with the interpreter when solving its task, taking into account its goal. They may contain requests to intelligent technology agents to perform certain functions. To find intelligent technology agent able to perform such functions the algorithm interpreter sends request to intermediary agent through the ontology interpreter of the problem domain, the basic ontology interpreter and the message receiving/sending subsystem. The goal adjustment algorithm allows adjusting agent's goal function in consequence of interaction with other agents. The belief base contains the agent's beliefs regarding the ontology, which can be supplemented and corrected by the belief correction algorithm in consequence of interaction with other agents and the domain model. Problem-solving protocol model stores the current state of the protocol model worked out by the agents of the problem-solving subsystem. It can be corrected by the problem-solving protocol adjustment algorithm due to the negotiations of the agents. Problem domain ontology is the semantic network based on the conceptual model of the problem being solved. This ontology is developed for each expert agent individually in accordance with the specialty of the expert, whose knowledge is modeled by the agent. In the general case, various independent teams can carry out the development of expert agents and their ontologies, therefore, ontologies can differ and even contradict each other. Problem domain ontology is not static, but changes by the problem domain adjustment algorithm during the process of solving the problem as a result of negotiations between agents of the problem-solving subsystem. Moreover, although during negotiations, the problem domain ontologies of various agents become more consistent, they do not become identical.

The architecture of the decision-making agent is shown in Fig. 9. The problem decomposition subsystem, based on the problem domain ontology analysis, distributes among the expert agents the tasks of the posed problem and the initial data necessary for their solution. Decision-making agent's solution evaluating subsystem calculates the index of the quality of solutions submitted by expert agents in accordance with own goal. If no solutions of satisfactory quality were found, this subsystem launches a new iteration of problem solving by CHIMAS. The base of decision-making algorithms stores a set of algorithms used by the agent when choosing the final decision depending on the problem-solving protocol. The interpreter of decision-making algorithms is a subsystem for execution of decision-making algorithms. Other bocks are similar to those of the expert agent architecture.

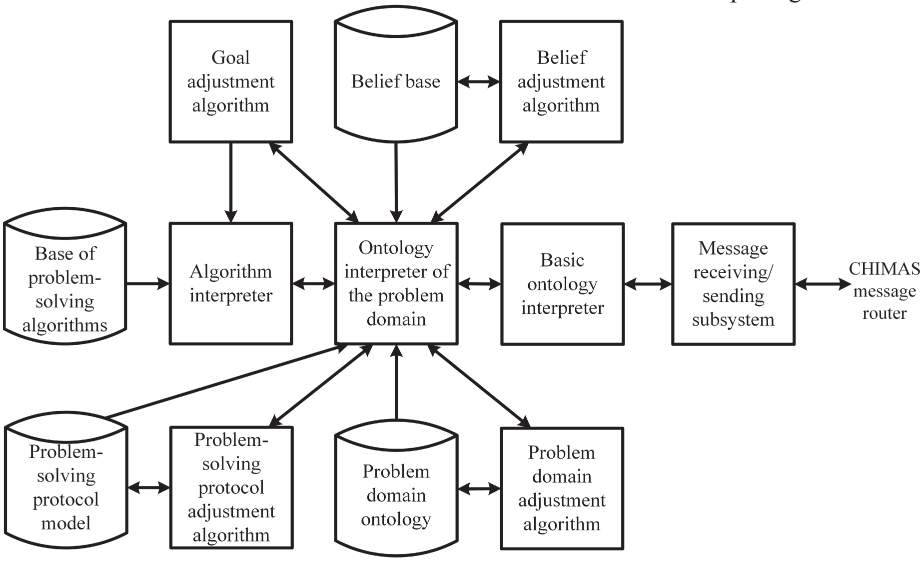

Fig. 8. The architecture of an expert agent

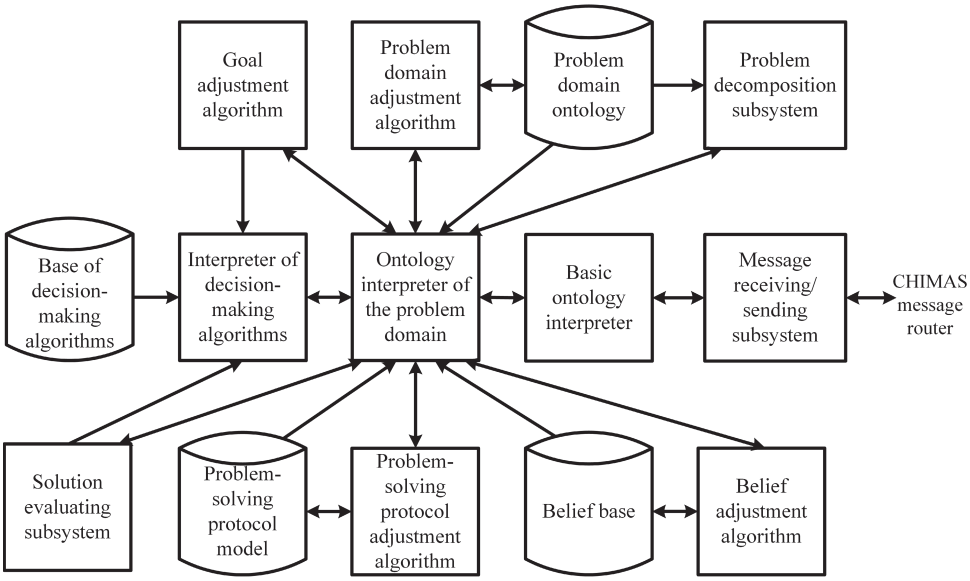

Fig. 9. The architecture of the decision-making agent

As can be seen from the analysis of agent architectures in Fig. 2 – 9, they are mainly reactive agents that perform functions specified by the developer in response to incoming messages from other agents or to user actions. The exception is expert agents who have dynamic models of goal setting and beliefs. Initially, the developers of the system set expert agents' goals, beliefs, and problem domain models; however, when working on problems, they exchange data and knowledge substantiating the proposed solutions to the problem, and, if necessary, modify their goals, beliefs, and problem domain models. Thus, after solving a certain number of problems, the goals, beliefs, and problem domain models of expert agents may differ from those set during development. Having the opportunity to request assistance in solving a problem from any of the intelligent technology agents, expert agents each time solving a new problem form a new integrated (hybrid) solution method relevant to it, demonstrating signs of "strong" self-organization, arising due to the distributed interaction of agents without explicit centralized management [21].

VI. System's effectiveness estimation

To evaluate accurately the effectiveness of the proposed CHIMAS architecture, it is necessary to accomplish its software implementation and conduct a series of computational experiments with various practical problems. At the moment, a rough estimate of the CHIMAS effectiveness can be given by comparing its capabilities with other implemented systems designed to solve problems in various areas of the economy.

For comparative analysis, two intelligent system is used: 1) hybrid intelligent system AGRO [22] for crop forecasting and planning of agricultural events, which allowed to increase the planning quality by 7-14%, and the planning speed by four times; 2) hybrid multi-agent intelligent system TRANSMAR [4], designed to solve complex transport and logistics problems and provided an increase in the efficiency of routing by more than 7%, and routing speed by 23% compared to methods existed at the moment of its creation. These systems were selected for comparative analysis due to the fact that CHIMAS inherits and develops the ideas and solutions implemented in them by A.V. Kolesnikov's Kaliningrad School of Artificial Intelligence. The problem decomposition and decision-making algorithms of the decision-making agent inherit the approaches used in the hybrid intelligent system AGRO. Ontology, message receiving/sending subsystems, message router, interface agent, intermediary agent, intelligent technology agents developed in TRANSMAR will be used in the implementation of CHIMAS.

As shown in Table I the proposed class of CHIMAS combines the representation of the heterogeneous functional structure of the problem with heterogeneous structure of the expert team and, creating conditions for solving practical problems without simplification and idealization.

Table I. Comparative analysis of the features of intelligent systems for solving heterogeneous problems

Features	AGRO	TRANSMAR	CHIMAS
Handling problem heterogeneity	+	+	+
Handling tool heterogeneity	+	+	+
Modelling expert reasoning	+	–	+
Autonomy of elements / agents	–	+	+
Ontology-based reasoning	–	+	+
Modelling group cohesion	–	–	+
Self-organization type	–	Weak	Strong

Designations: + - feature present; – - no feature

Due to the presence of mechanisms for coordinating goals and domain models of agents of the problem-solving subsystem, as well as developing coordinated problem-solving protocol in the intelligent system, the cohesive behavior of system agents is ensured, which allows overcoming disagreements and avoiding conflicts caused by differences in problem models and goals for solving it. The agent-facilitator protects the system from the possible negative effects of excessive cohesion of agents, such as conformism. As a result, CHIMAS dynamically rebuilds its functioning algorithm; each time when working on a problem, it develops new hybrid intelligent method relevant to it. Cohesion modeling ensures the development of the intelligent system and its self-organization in the strong sense [21], that is, arising due to the distributed interaction of agents without explicit centralized management of this process by one of them, which is relevant to small teams of experts solving problems "at round-table". Thus, CHIMAS has advantages over AGRO and TRANSMAR and more relevant to real expert teams solving problems in dynamic environments, therefore, as result of its software implementation, performance indicators could be no worse than those of reviewed intelligent systems could.

VII. Conclusion

Approaches to the definition of the concept of cohesion in social psychology and, in particular, in the group dynamics are considered, the relevance of modeling this state of the team and the processes leading to it in systems based on the principles of synergistic artificial intelligence is shown. The CHIMAS model is presented, containing mechanisms for coordinating goals and domain models, as well as developing the problem-solving protocol by agents without external control of this process. Based on this model, the functional structure of such a system and the architectures of its agents have been developed, demonstrating the composition, functionality and relationships that arise between agents in the process of solving problems. Modeling agent cohesion ensures the development of an intelligent system and its self-organization in a strong sense, because of which it dynamically restructures its functioning algorithm, each time when working on a problem, developing a hybrid intelligent solution method relevant to it.

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