About Focusing on Relevant Information Used by Agents in Reasoning in Intellectual Systems of Hard Real-Time

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Abstract—**We consider questions about focusing only on relevant information used by agents reasoning in intellectual systems of hard real-time. We offer the method to find the relationship of relevance between agent's knowledge and tasks solved by this agent and we also offer the method to focus attention of agent on relevant information providing his stability to anomalies using metareasoning, metaknowledge and cognitive modeling.**

***Keywords*—hard real-time, relevant information, focusing, metareasoning, stability, active logic.**

I. INTRODUCTION

As we know for systems of hard real-time, it is important to be able to estimate the amount of time for solving tasks that these systems have for thinking until moment when it is late for thinking. For this, you must be able to correlate in time steps and results of reasoning with events happening in external domain. Reasoning of this type called reasoning situated in time.

To formalize reasoning situated in time different versions of active logic were suggested. As rule, traditional epistemic logics give us possibility to reason about process of reasoning of agent as a whole after its actual implementation. Active logic gives us a possibility to witness process of reason-ing of agent while this process is implementing.

The general concept of the active logic set forth in [Elgot-Drapkin, 1998]. As a model of deduction, logic is characterized by an active language, lots of deductive rules, as well as the set of "observations". If we assume that the agent says, being in a static environment, many observations can be considered as part of the initial knowledge base of a deductive system, i.e., as a set of statements that sup-port the deductive process by which new knowledge generated. However, the use of the surveillance function allows us to simulate the dynamic environment information about this environment is sup-plied to the agent as this environment changes.

Time reasoning is characterized by performing cycles of deduction, called steps [Purang et al., 1999]. Since the basis of the active logic model is a discrete-time, these steps serve as the interim standard - time is measured in steps. Agent's knowledge is associated with step index on which they were first get. The principal difference between the active logic and other temporal epistemic logics is that the temporal arguments introduced in the language of their own agent theories. Thus, the time parameter is associated not only with each statement (the formula), which is explicitly known by the agent, but also a deductive inference rules. That the agent learned at step t (t-knowledge) is used to form a new knowledge for output in step (t + 1).

II. RELATIONSHIP OF RELEVANCE BETWEEN AGENT'S KNOWLEDGE AND TASKS SOLVED BY THIS AGENT

Determination of relationship of relevance between agent's knowledge and tasks solved by this agent is a key factor in the simulation of dynamic systems; it gets particular relevance for hard real-time systems. Developing a method to define relationship of relevance following assumptions were made.

The agent at each time point solves exactly one problem.

Each of the possible solved by agent tasks corresponds to exactly one of the possible modes of his work, one of which is a standard ("regular"), and the others correspond to the different classes of possible contingencies, which, in the general case, can be several . Change of operation modes of agents is irreversible: the normal mode may be replaced by an unexpected, but not vice versa; one of the non-standard modes can be replaced by another and in the future it will no longer be used.

Agent's knowledge represented as a first-order logic formulas or any of its conservative expansion. Each formula can be relevant in relation to all possible modes of operation of the agent or can be obviously irrelevant to some (but not all) of them.

Agent's reasoning for solving the current task it can be represented as a cyclic process of successive generation of sets of the so-called explicit knowledge, with each such set is associatively connected with the time it was generated. Generation of new set of explicit knowledge is a result of execution of next deductive cycle generally consisting of the following stages:

- focusing attention of agent on knowledge relevant to the current mode of operation;

- the use of inference rules.

The first step is executed only when changing the operation mode of agent. At this stage, the current set of explicit knowledge (obtained as a result of the previous deductive cycle) is filtered, which resulted in agent's focus includes only the knowledge that, in accordance with the strategy used by the agent, are relevant to the current mode of operation. This filtering allows in many cases significantly reduce the execution time of deductive cycle. Note that the change of operation modes of agent occurs when abnormal situations appear jeopardizing the implementation of the agent of its primary function in the allotted for this time, and this is due to the need to change its mode of operation.

At the stage of the application of rules of inference there is a comparison with the information that is fallen in the focus of attention of the agent during the execution of the deductive cycle, result-ing in form of the so-called set of special cases (specific instances) of inference rules obtained by substituting metavariables included in these rules of inference, by specific values (they are formulas, trapped in the focus of the agent at the beginning of its operation in this mode). Note that in the gen-eral case each inference rule as a result of comparison may have from zero to more than one concrete instance. Next comes the application of specific instances of inference rules, which result in form a set of formulas, the union of which with a lot of explicit knowledge gained as a result of the previous deductive cycle (the elements of this set are also formulas), results in a new current set of explicit knowledge. Note that the knowledge acquired by the agent as a result of observation for the external environment, including those get from other agents in the form of messages that do not stand out in a special class, and for ease of review, shall be deemed as received by the application of rules of inference, the only condition of applicability of which are points in time when the relevant observations were made. Although the formulas, once got in a set of explicit knowledge of the agent, are struck out in the future, their use for the generation of specific instances of inference rules can be blocked if they come into direct conflict with other formulas, located in the same set of explicit knowledge.

Thus, the results of the deductive cycles execution depend on how the relationship of relevance is determined between the formulas, which are the elements of explicit knowledge sets and possible modes of operation. In the simplest case it is assumed that all available explicit knowledge of agents is relevant to any possible mode of its operation. This approach has the obvious advantage, consisting in the fact that this excludes the possibility of losing information due to an error at step of focusing attention of agent the focus doesn't get knowledge important from the point of view of the current situation. On the other hand, the current explicit knowledge of the agent may have a very large volume, and not all of them may be relevant in every moment of time and current mode of operation appropriate to this time. In this case, with correct focus of attention due to the refuse of considering irrelevant information a significant amount of time can be saved, which is of great importance when working in hard real-time. Note, however, that such a situation occurs only when using the concept of time as an external entity. In other systems of active logic the length of deductive cycles serves as a time model, one is the inner entity and assumed to be constant, making it pointless to focus attention of the agent on information relevant to the current time - the length of deductive cycles does not change because of this. It is clear that in order to determine the relationship of relevance between the formulas included in the set of explicit knowledge and current modes of functioning of the agent, meta-level information is needed. The following will be considered an implicit way of determining the relationship of relevance between formulas and modes of functioning of the agent.

The relationship of relevance between knowledge (logical formulas) and solved by agents tasks (or its current operating mode) is a binary and antisymmetric. It is not transitive and not reflective, and may be defined both intensionally, for example by the algorithm, for each pair (a formula or operation mode) it gives for finite number of steps response "yes" or "no" depending on whether this couple is in the relationship of relevance and extensionally, by explicitly enumerating all pairs of this kind, together determining the relationship of relevance. The simplest and most reliable way of determining the relationship of relevance between the formulas and modes of agent's operation in terms of possible errors made at the stage of the focus, is a recursive definition for each of the formulas of language of agent of plurality of its modes of operation, for which the formula is obviously non-relevant.

III. Method of agent focusing only on the relevant information while ensuring its stability to anomalies during the reasoning in the hard real-time.

One of the most important and complex problems of intellectual system theories (including multi-agent) is to ensure the stability of intelligent agents to unforeseen situations in advance («anomalies») [Anderson et al., 2005]). Anomalies originate both due to unforeseen changes occurring in the external environment (part of which may be other agents of multi-agent systems), and because of the imperfections of existing agent's knowledge about it, and these anomalies neg-atively affect its functioning. Abutment of agents to anomalies is especially important in hard real-time systems, which is characterized by the existence of the critical time threshold (deadline) of facing the systems task solution, the excess of which is fraught with catastrophic consequences. A typical example of the anomaly for such systems is a situation where an event anticipated at the designated time, however, did not come. This event may be caused not only by the state of the external environment, but by the current state of knowledge the agent. In both cases one can speak of appearance of threat of exceeding the time allotted to the solution of the problem, i.e. the catastrophic deterioration of the functioning of both the agent and the system as a whole. It is clear that in the systems of hard real-time time resource of agent is severely limited. Next, we consider the issue of increasing the resistance to anomalies of agents with limited time resources through the use of the concept of metacognition, implemented by means of active logic.

The term "metacognition" was introduced by J. Flavell [Flavell, 1979], [Flavell, 1987] and de-fined by him as an awareness of person of their cognitive processes and related strategies, or, as he put it, as "knowledge and acknowledge with respect to enforcement-cognitive effects" In the other sources metacognition is often defined simply as a reflection of thinking (e.g. [Metcalfe et al., 1994]), bearing in mind in this "second-order knowledge." In the future, instead of the term “thinking” we will use more appropriate for the artificial intelligence systems term “reasoning”.

Studies of metacognition expanded information processing theory. The key in this new psychological paradigm was the idea of thinking as the flow of information inside and outside the system of mental structures: how information is stored and restored in the mental structures, how these structures evolve, how the storage and correction management happens, etc.

According to the model of Flavell person’s ability to control "a wide variety of informative initiatives takes place through action and interaction between the four classes of phenomena" [Flavell, 1979]:

- metacognitive knowledge,
- metacognitive feeling
- goal (or goals)
- actions (or strategies).

The model includes the knowledge of the three common factors:

- Knowledge of the functioning of "cognitive processing";

- Knowledge of the task, its requirements and how these requirements can be met as conditions change;

- Knowledge of strategies to accomplish this task (cognitive strategies to achieve goals, and metacognitive strategies to monitor the progress of cognitive strategies).

Metacognitive knowledge can influence the direction of cognitive initiatives through a deliberate and conscious search in the memory or the unconscious and automatic cognitive processes.

The difference between cognitive and metacognitive strategies should be noted. The former help the person to achieve a specific cognitive goals (for example, to understand the text), and the latter are used to control succeeding of this purpose (e.g., self-questioning for understanding of the text). Metacognitive components are usually activated when knowledge fails (in this case it may be a lack of understanding of the text at first reading). Such failure activates metacognition, allowing the person to correct the situation. Thus, metacognition is responsible for active monitoring and consistant regulation of cognitive processes.

In the context of the use of metacognitive principles for improving the resistance to anomalies of rational agent with limited time resource in the work [Anderson et al., 2006] it was proposed the concept of "metacognitive" cycle. It is defined as the cyclical performance of the following three stag-es:

- Self-observation (monitoring);

- Self-assessment (analysis of detected abnormalities);

- Self-improvement (regulation of the cognitive process).

Note that in other works devoted to metareasoning (or metacognition) ([Brown, 1987], [Cox et al., 2007], [Raja et al., 2007]), the term "metacognitive" cycle of specified type also used. Common to all these works is the approach based on stage of self-observation, which reveals the presence of anomalies, is built taking into account the binding of possible actions of agent that affect the external environment, the expected on-consequences of these actions. An indication of the presence of anomalies in this case is a mismatch between the expectations of the agent and the incoming information about the external environment. At self-observation stage, they are reduced to the verification of the presence for the agent in the discourse of formal signs and in presence of anomalies in the agent’s reasoning, solving certain problems. These formal features are the so-called direct contradictions in knowledge of agent. Formally, the presence of a pair of contraries formulas expressing the current knowledge of the agent called direct contradiction.

Because anomalies in the hard real-time systems mainly linked to the delay of occurrence of the expected responses of external environment of an agent, such situations must be detected in the monitoring process first. At the stage of self-assessment level of threat to the quality of functioning of the agent, which is fraught with anomaly detection, is set and at the stage of self-improvement, if the threat is real, a new strategy to address the problem faced by the agent is chosen. A typical output from such situations is the transition to the new strategy which requires a shorter time resources to car-ry out, but provides although acceptable, but less quality solutions facing the agent problem in comparison with the "old" strategy [Vinkov and other ., 2010].

Thus, a logical system, formalizing reasoning agent with limited resources, should give him the opportunity to evaluate the available time resource of agent at any given time so that depending on the results of the evaluation the agent could change the course of his reasoning (temporal sensitivity property of agent [Elgot-Drapkin, 1998]). In addition, the agent must be tolerant to inconsistencies in their knowledge and to be able to identify them. The prerequisite is also the ability of the agent to assess at each time the completeness of existing knowledge and to realize not only what he knows but what he does not know.

$\frac{t:\phi,\psi}{t+1:\phi\wedge\psi}$ - conjuction

$\frac{t:\phi\wedge\psi}{t+1:\phi}$ - detaching

$\frac{t:\phi}{t+1:\phi}$ - inheritance

$\frac{t:\phi,\phi\rightarrow\psi}{t+1:\psi}$ - modus ponens

Different levels of complexity of theories of active logic associated with involvement in the process of reasoning of agents with three different mechanisms: the timing, providing a temporal sensitivity of reasoning of agents, self-knowledge (agents’ ability to acknowledge both what they know at any given moment of time, and what they don’t know at any given moment of time) and detect inconsistencies in current knowledge.

Timing is achieved through a special one-place predicate now (.). In relation to him, the following applies:

$$\frac{t:now(t)}{t+1:now(t+1)}$$

Self-knowledge is achieved through the rule of inference:

$$\frac{t:\varphi,sub(\phi,\varphi),[\phi]}{t+1:now(t+1)}$$

where ϕ - any formula, not known to the agent i at step t, but it is a well-known formula of subformula ϕ known to him, i.e. the perceived by agent, sub (.,.) - double-place metapredicate expressing the relation "to be subformula», $[\phi]$ - notation, meaning that the formula ϕ absent in current knowledge the agent at step t. K (.,.) - double-place metapredicate, expressing the fact that the agent knows some formula at some point in time. Detection and elimination of contradictions is achieved through the rule of inference:

$$\frac{t{:}\varphi,\neg\varphi}{next\ t{:}contra(i,\varphi,\neg\varphi)}$$

where contra (.,.,.) – a special three-place metapredicate having the value "true" if at the moment of time t the current knowledge of the agent containing formula ϕ and $\neg\phi$.

IV. Conclusion

In this paper we propose a method of focus of the intelligent agent on relevant information in-formation while ensuring its resistance to anomalies. The method is based on metareasoning mecha-nisms, metacognition and cognitive modeling. It implemented using the active logic formalism. Promis-ing objectives of the study are to develop a method of decomposition, in which the subtasks of the same task are interacting with each other; distribution and redistribution method subtasks between agents depending on the current situation based on the concept metacognition; model of goal setting in hard real-time system.

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О ФОКУСИРОВКЕ ВНИМАНИЯ НА РЕЛЕВАНТНОЙ ИНФОРМАЦИИ ПРИ РАССУЖДЕНИЯХ АГЕНТОВ В ИНТЕЛЛЕКТУАЛЬНЫХ СИСТЕМАХ ЖЁСТКОГО РЕАЛЬНОГО ВРЕМЕНИ

Фоминых И.Б., Романчук С.В.

Рассматриваются вопросы фокусировки внимания только на релевантной информации при рассуждениях агентов в интеллектуальных системах жесткого реального времени. Предлагается способ определения отношения релевантности между знаниями агента и решаемыми им задачами и метод фокусировки внимания агента на релевантной информации при обеспечении его устойчивости к аномалиям на основе метарассуждений, метапознания и когнитивного моделирования.