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On Intelligent Decision Making in Multiagent Systems in Conditions of Uncertainty

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***Abstract*—The paper deals with the problem of decision making in a multi-agent environment. By the example of the problem of determining states in a partially observable world, the main stages of decision making in a multiagent environment are considered using a knowledge base based on predicate logic of the first order. A method for solving the problem, characterized by higher productivity compared to the classical one, is proposed. An intelligent information technology is proposed for integrating declarative languages using the example of Prolog with the NetLogo multiagent simulation environment, which is characterized by using the capabilities of the logic output mechanism of the Prolog language.**

Keywords—artificial intelligence, logic programming, multiagent modeling, decision making, knowledge bases

I. INTRODUCTION

The multiagent approach allows solving problems of modeling population dynamics with high accuracy [1-4]. The most effective for the implementation of multiagent systems with different types of agents are models based on intelligent agents [5-6]. Despite research in this area, the available tools do not yet allow the free use of elements of logic programming [7].

If the agent knows enough facts about its environment, the corresponding logical approach allows him to formulate plans that are guaranteed to work [8]. Such an organization of the functioning of the agent is very convenient. Unfortunately, agents almost never have access to all the necessary information about their environment. Therefore, agents must act under conditions of uncertainty. [9]

Consequently, a separate interest in studying multi-agent simulation and interaction of agents is an extension of the autonomy of agents by endowing them with the ability to draw logical conclusions and make decisions [10-12]. To formalize the decision-making mechanism in a multi-agent environment, let us consider an example with the spread of the incidence of the epidemic process [13-14], which implies the interaction of intelligent agents in conditions of uncertainty.

II. PROBLEM STATEMENT

Three agents donated blood for hepatitis B. In order to save money, the laboratory uses a pool of blood sera, that is, sera from several patients are mixed. If the result is negative, then all patients are healthy, if positive, one of the patients is ill, and then further research is being conducted [15]. Their states can be either "healthy" or "sick", but suppose that all agents are sick. Each agent does not know his condition. The doctor conducting the blood tests asks the agents about their lifestyle, assesses each person's risk group and passes this information to two other agents [16-18]. He asks agents if they know about their condition. Each agent responds negatively. After research, the doctor announces "At least one of you is sick," and then asks them again in turn. Agent 1 says no, Agent 2 also says no, but when the doctor asks Agent 3, he says yes. How is it possible that Agent 3 can finally figure out his condition? Before announcing that at least one of them was sick, no agent was able to tell if he was sick or not. What changes have occurred after the announcement? It would seem that the ads did not reveal anything new; each agent could already assume that among them there is at least one patient, because he knows the information about their belonging to a risk group [19].

Considering that each of the agents has heard that there is at least one patient, agent 3 can determine his condition, thinking this way: "No" of agent 1 means that either I or agent 2 is at risk, that is, most likely sick. Agent 2 knows this, so if I was not at risk, Agent 2 would say yes. But Agent 2 said no, because I'm at risk, which means it's most likely sick."

Although each agent already knows (from perception [20]) the fact that at least one agent is sick, the key point is that publishing about a person makes this fact common knowledge among agents. (Indirectly, it is also assumed that common knowledge is that each agent can perceive information and reason rationally [21].) This example demonstrates the consequences of interactive considerations and the strength of general knowledge [22].

Let us now try to formalize some of the concepts that appear in the example. The starting point is that the state of the world is partially observed for agents [23]. Partly

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observed in the world, the agent's perception provides only partial information about the true position using a deterministic or stochastic observation model. In this example, this model is a deterministic model [24-26].

Let S be the set of all states, and let $s \in S$ be the current (true) state of the world. We assume that the perception of the *i*th agent provides information about the state s through an information function $P_i : S \mapsto 2^S$ that causes s to $P_i(s)$, which is non-empty subset of S, called the information set of the agent *i* in the state *s*. The meaning of the information set is that when the true state is *s*, the agent *i* thinks that any state in $P_i(s)$ can be a true state. The set $P_i(s)$ will always contain *s*, but in essence it is the only thing that the agent *i* knows about the true state. In the case of multiple agents, each agent has its own information function.

In the given task, the state of the world is a vector of three elements containing the states of the agents. Let *I* and *H* indicate the state of infected and healthy, respectively. They are used in eight states $S = \{a, b, c, d, e, f, g, h\}$ (Table 1).

TABLE I. EIGHT STATES OF WORLD

	a	b	c	d	e	f	G	H
1	I	I	I	I	H	H	H	H
2	I	I	H	H	I	I	H	H
3	I	H	I	H	I	H	I	H

Suppose that true state is $s = a$. The condition is partially distinguishable for each agent; each agent can directly see the states of only two of the three agents. In other words, in any state, the set of information for each agent contains two equally probable states in which only its own state differs. Generally speaking, the information function of the agent divides the state space into a set of intersegment subsets, called cells, which together form a separation P_i from S. The information set $P_i(s)$ for the agent *i* in the true state *s* is the cell from P_i which it is contained *s*, and the union of all cells in P_i is *S*.

Based on the information function, we can calculate the separation of agents in the problem under consideration.

$$\begin{aligned} P_1^t &= \{\{a,e\},\{b,f\},\{c,g\},\{d,h\}\} \\ P_2^t &= \{\{a,c\},\{b,d\},\{e,g\},\{f,h\}\} \\ P_3^t &= \{\{a,b\},\{c,d\},\{e,f\},\{g,h\}\} \end{aligned} \tag{1}$$

where t denotes the step in time before entering general information.

It is clear that in the true state $s = a = III$, no agent knows his state as long as the corresponding cell of each division co-holds two equilibrium states. Thus, agent number 1 considers that the states *a* and *e* are possible, agent number 2 – that states *a* and *c,* agent number 3 – that states *a* and *b* are possible.

III. Development of a Method for Solving a Problem in a Multi-agent Environment

A modified method for solving the problem was created and an algorithm was formulated (Fig. 1), designed for any number of agents. The algorithm is as follows.

The number of agents is specified and a state is determined for each agent. It creates a world based on a specified number of agents. For each agent, partitions are calculated and information sets are selected based on the states that other agents have. The observer contributes general information. Successively each agent is asked whether he can name his state.

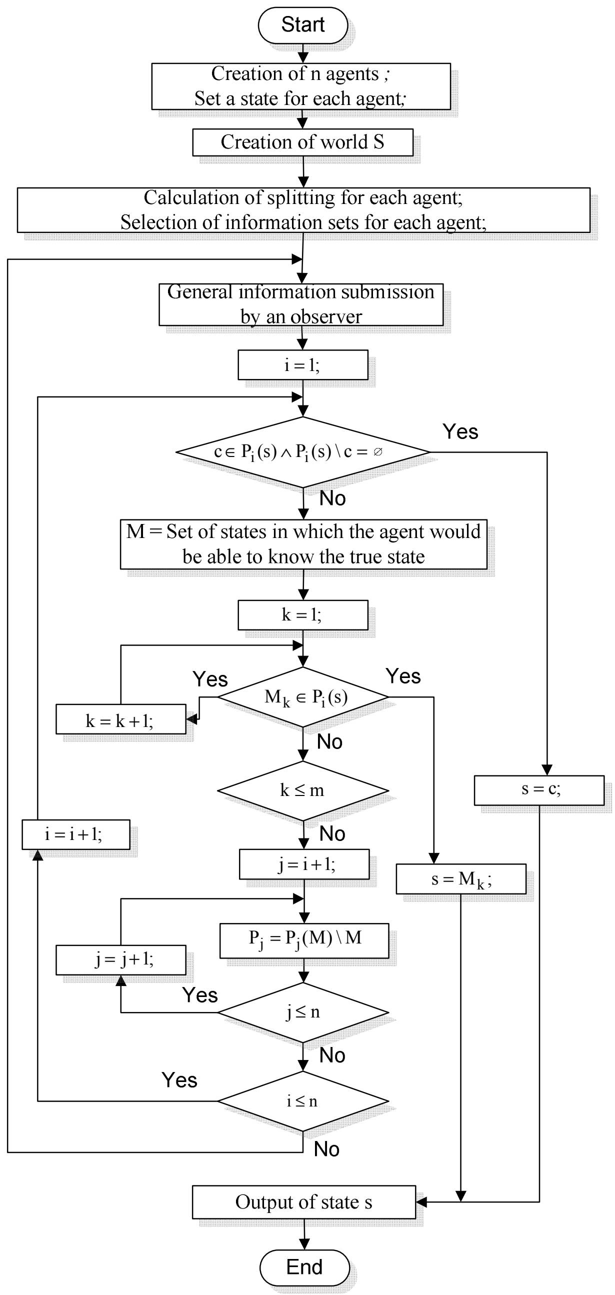

Fig. 1. Block diagram of method algorithm

Explanation of symbols on the block diagram:

- S is set of all states (world);
- s is true state;

- P_i is partitioning for *i*th agent;
- $P_i(s)$ is information set of *i*th agent;
- *n* is agents quantity;
- *i* is the counter of the external agent cycle;
- *j* is counter of the internal agent cycle;
- *M* is the set of states in which the agent would know the true state;
- *m* is the number of states in *M* set;
- *k* is counter on set *M;*
- *c* is any state of set *S*.

At the same time, each agent, waiting for his turn, performs the following sequence of actions:

1) Check the obvious answer. If there is only one state in the information set, then it is this state that is true. Otherwise, go to step # 2.
2) Search for states in which the agent could accurately answer the question about his condition.
3) View all found states. If the state is included in the information set, then this state is true and the agent says that he can name his state. Otherwise, go to step # 4.
4) If none of the found states is in the information set of the agent, then he cannot determine his state. The agent is excluded from consideration, and agents whose turn has not yet arrived, cut off the states found by the current agent.
5) Go to the next agent.

A comparative analysis of the performance of the original and modified methods of solving the problem was carried out. As can be seen from the graph in fig. 2, the modified method has a higher productivity due to a decrease in the number of operations required. In this case, a single operation means the operation of reading an element from an array or deleting an element from an array. The sets of operations inherent in both algorithms are not taken into account.

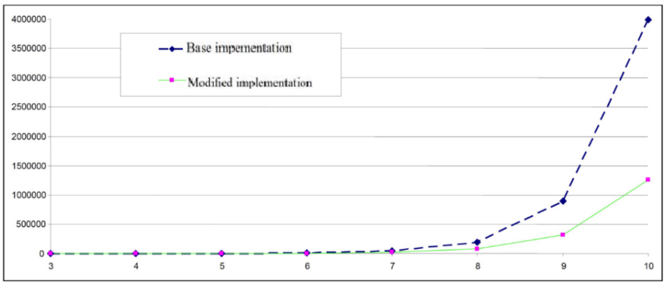

Fig. 2. Productivity graphs of the basic and modified methods

IV. Implementation of the Method of Intellectual Interaction

The developed method is implemented in the Prolog language, and a multi-agent approach is provided using the NetLogo environment. To ensure interoperability between NetLogo and Prolog, it is implemented using an extension for NetLogo, which is written by Sano in the Java language and created specifically for this task. The extension includes the implementation of three NetLogo operators:

```
import org.nlogo.api.*;
public class RationalAgents extends DefaultClassManager {
  public void load(PrimitiveManager primitiveManager)
  {
        primitiveManager.addPrimitive("start_prolog",
new StartEngine());
        primitiveManager.addPrimitive("answer",      new
Answer());
        primitiveManager.addPrimitive
("get_possible_states", new GetPossibleStates());
  }
}
```

The Answer class accepts all the necessary information for the logical output, pro-cesses the objects from NetLogo and makes a request to Prolog. The output returns the response from Prolog.

The GetPossibleStates class returns states that will be cut off by other agents if the current agent cannot recognize its color.

In addition, there is a class PrologClass, which accepts requests in accordance with the requirements of Prolog, performs requests, and then processes the responses, leading them to the form necessary to transmit them to NetLogo.

After the creation of the Prolog program and the expansion necessary for working with it, the implementation stage of the algorithm in NetLogo follows, which performs all the necessary preparatory work (generating the world for a specified number of agents, defining information sets, etc.), and also provides a visual display of the process solving the problem. The created system is shown in Fig. 3.

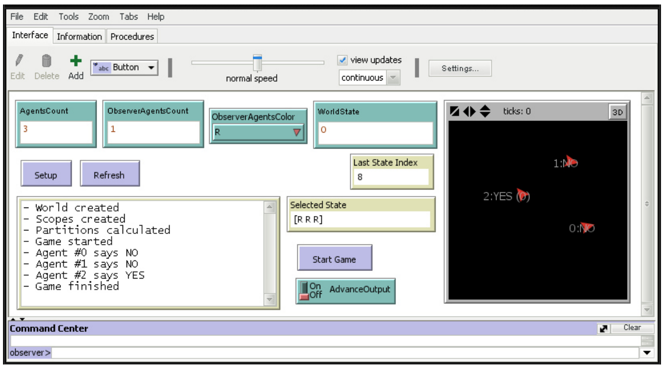

Fig. 3. Program realization of method

V. Conclusions

Thus, the developed mechanism for the integration of the Prolog language and the NetLogo environment allows solving decision-making problems in a multi-agent environment using a knowledge base based on the first-order predicate logic. The use of the proposed mechanism is shown by the example of solving the problem of observability of states in conditions of uncertainty.

Using the example of the developed modified method, the possibilities of increasing the efficiency of inference in a multi-agent environment are revealed.

The proposed information technology of integrating declarative languages with the multiagent modeling environment NetLogo can be applied to a wide range of tasks: expert and advising systems, automation of technological processes using robotics, emergency response systems in emergency situations, socio-economic monitoring systems.

Further prospects for research in this area is the complication of the internal structure of intelligent agents, as well as the expansion of the range of knowledge representation models.

REFERENCES

[1] D. Chumachenko et al., "On agent-based approach to influenza and acute respiratory virus infection simulation," in 14th International Conference on Advanced Trends in Radioelectronics, Telecommunications and Computer Engineering, TCSET 2018. Proceedings, pp. 192-195, 2018.

[2] D. Chumachenko, "On Intelligent Multiagent Approach to Viral Hepatitis B Epidemic Processes Simulation," in Proceedings of the 2018 IEEE 2nd International Conference on Data Stream Mining and Processing, DSMP 2018, pp. 415-419, 2018.

[3] D. Chumachenko, S. Yakovlev, "On Intelligent Agent-based Simulation of Network Worms Propagation," in 2019 15th International Conference on the Experience of Designing and Application of CAD Systems (CADSM), pp. 3.11-3.14, 2019.

[4] D. Chumachenko, K. Chumachenko, S. Yakovlev, "Intelligent simulation of network worm propagation using the Code Red as an example," Telecommunications and Radio Engineering, vol. 78 (5), pp. 443-464, 2019.

[5] S. J. Russel, P. Norvig, "Artificial Intelligence: a modern approach," Prentice Hall, p. 1152, 2012.

[6] N. Vlasis, "A Concise Introduction to Multiagent Systems and Distributed Artificial Intelligence," Synthesis Lectures on Artificial Intelligence and Machine Learning, vol. 1, no. 1, pp. 1-70, 2007.

[7] I. Meniailov I., et. al. "Using the K-means Method for Diagnosing Cancer Stage Using the Pandas Library," CEUR Workshop Proceedings, vol. 2386, pp. 107-116, 2019.

[8] A. Sadilek, H. Kautz, "Location-Based Reasoning about Complex Multi-Agent Behavior," Journal of Artificial Intelligence Research, vol. 43, pp. 87-133, 2012.

[9] C. Amato, "Decision-Making Under Uncertainty in Multi-Agent and Multi-Robot Systems: Planning and Learning," in Proceedings of the Twenty-Seventh International Joint Conference on Artificial Intelligence (IJCAI-18), pp. 5662-5666, 2018.

[10] N. Bulling, "A Survey of Multi-Agent Decision Making," KI - Künstliche Intelligenz., pp. 1-12, 2014.

[11] M. Kaufman, "Local Decision-Making in Multi-Agent Systems," A thesis submitted for the degree of Doctor of Philosophy, Michaelmas Term, p. 185, 2010.

[12] J. Amudhavel, et. al., "A Comprehensive Analysis on Multi Agent Decision Making Systems," Indian Journal of Science and Technology, vol. 9 (11), pp. 1-5, 2016.

[13] M. Mazorchuck et. al., "Web-Application Development for Tasks of Prediction in Medical Domain," in 2018 IEEE 13th International Scientific and Technical Conference on Computer Sciences and Information Technologies (CSIT), Lviv, Ukraine, pp. 5-8, 2016.

[14] Yu. Polyvianna, et. al., "Computer Aided System of Time Series Analysis Methods for Forecasting the Epidemics Outbreaks," in 2019 15th International Conference on the Experience of Designing and Application of CAD Systems (CADSM), Polyana (Svalyava), Ukraine, pp. 7.1-7.4, 2019.

[15] N. Beer, "Accuracy of hepatitis C virus core antigen testing in pools among seroconverters," Transfusion, vol. 46 (10), pp. 1822-1828, 2006.

[16] N. Dotsenko, et. al.. "Management of Critical Competencies in a Multi-Project Environment," CEUR Workshop Proceedings, vol. 2387, pp. 495-500, 2019.

[17] N. Dotsenko, et. al., "Modeling of the processes of stakeholder involvement in command management in a multi-project environment," in 2018 IEEE 13th International Scientific and Technical Conference on Computer Sciences and Information Technologies, CSIT 2018 – Proceedings, Lviv, Ukraine, pp. 29-32, 2018.

[18] N. Dotsenko, et. al. "Project-oriented management of adaptive teams' formation resources in multi-project environment," CEUR Workshops Proceedings, vol. 2353, pp. 911-923, 2019.

[19] P. R. Williams, "Artificial intelligence in co-operative games with partial observability," PhD thesis, University of Essex, 152 p.

[20] J. Walton-Rivers, et al., "Evaluating and Modelling Hanabi-Playing Agents. Congress on Evolutionary Computation," in CEC'17. IEEE Conference On. IEEE, pp. 1382–1389, 2017.

[21] H. Osawa, "Solving Hanabi: Estimating Hands by Opponent's Actions in Cooperative Game with Incomplete Information," Workshops at the Twenty-Ninth AAAI Conference on Artificial Intelligence, 2015.

[22] S. Lee, J. Togelius, "Showdown AI competition, Computational Intelligence and Games (CIG)," in 2017 IEEE Conference on. IEEE, pp. 191–198, 2017.

[23] Ch. Gu, X. Wang, Zh. Li, "Synthesis of Supervisory Control With Partial Observation on Normal State-Tree Structures," IEEE Transactions on Automation Science and Engineering PP(99), pp. 1-14, 2018.

[24] K. Bazilevych, et al., "Stochastic modelling of cash flow for personal insurance fund using the cloud data storage," International Journal of Computing, vol. 17 (3), pp. 153-162, 2018.

[25] V. P. Mashtalir, S. V. Yakovlev, "Point-set methods of clusterization of standard information," Cybernetics and Systems Analysis, vol. 37, no. 3, pp. 295-307, 2001.

[26] V. P. Mashtalir, V. V. Shlyakhov, S. V. Yakovlev, "Group structures on quotient sets in classification problems," Cybernetics and Systems Analysis, vol. 50, no. 4, pp. 507-518, 2014.