The Decision-Making System Based on Adaptive Agents

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***Abstract* — In this paper are presented the results of designing a decision-making system based on adaptive agents. In the design process, the agent's functional model and sequence of operations were developed to transform data, information and knowledge needed to achieve the optimum value of the environment state. The adaptability of the decision-making system is achieved through the calculation of a new knowledge model as a result of an analysis of the environment state and the old model of knowledge.**

***Index Terms* — multi-agent systems, collective agents, knowledge model, decision-making, adaptive systems, adaptive agent model.**

I. INTRODUCTION

A multi-agent system is a set of homogeneous or heterogeneous interacting intellectual agents. Such systems are used to solve complex problems that are difficult or impossible to solve for a stand-alone agent or a centralized system. Multi-agent systems are a class of open systems, with dynamically developing network topology, internal architecture and intellectual abilities. Requirements for Multi-agent systems are discussed in references [1, 2, 3], where the basic theoretical, algorithmic and technical features are stated.

Regardless of the application and class of tasks to be performed, intelligent agents must have the following properties [4]: autonomy, social behaviour, reactivity, activity, basic knowledge, beliefs, goals, desires, commitments, intentions, rationality, truthfulness, kindness and mobility.

As noted in [4], modern Multi-agent systems form a single computing architecture with dynamic topology. The result of the agent's interaction is not just the sum of their constituent technical and software tools, but it is a single system with progressive knowledge. Today Multi-agent systems are considered not only as a fundamentally new information technology, formed on the basis of the information and telecommunication technologies merger, but also as a new paradigm for software and hardware designing.

Collective behaviour and collective decision making is the main condition for the functioning of Multi-agent systems. One way of collective decision-making is the exchange of data or knowledge between agents [5, 7]. Another way is to use mobile program code that moves from one agent to another, solving part of the global task based on the hardware of this agent [6, 7]. Both options have their advantages and disadvantages, which can be compensated by the addition of special technical or software tools.

II. STATEMENT OF THE PROBLEM

Suppose that, in the N - dimensional space Environment (Figure 1) is given a system of collective decision-making CA consisting of N agents. Space Environment generates $\boldsymbol{X}=\left\{\boldsymbol{x}_i, \forall \boldsymbol{i}=\overline{1,\boldsymbol{N}}\right\}$ environment state vector.

The aim of this paper is to design a collective agent for the synthesis of adaptive decision-making systems that implement the following condition:

$$\boldsymbol{X}\xrightarrow[X\to\min/\max]{CA}\boldsymbol{Y}, \qquad (1)$$

where: $\boldsymbol{X}$ - the vector of the state of the environment; $\boldsymbol{Y}=\left\{\boldsymbol{y}_i, \forall \boldsymbol{i}=\overline{1,\boldsymbol{N}}\right\}$ - the vector of environmental impact; $\boldsymbol{CA}$ - a Multi-agent system with initial knowledge for perception, processing and impact on the environment, and the computation of new knowledge; $\boldsymbol{X}\to\min/\max$ - the goal achieved when impact on the environment.

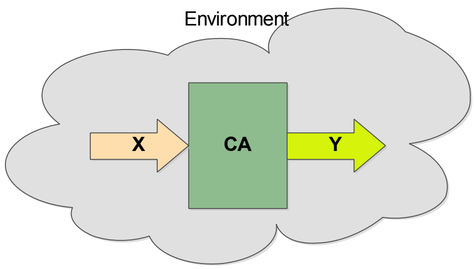

Figure 1. The interaction of the system of collective agents with the environment.

III. FUNCTIONAL MODEL OF THE COLLECTIVE AGENT

The functional model of the collective agent is presented in Figure 2, where: x - the input signal of the state of the environment; $\boldsymbol{ADC}$ - analog-to-digital converter; $\boldsymbol{RgD}$ - the register of the state of the environment input data; $\boldsymbol{RAM\ Inf}$ - Random Access Memory containing information about the state of the environment; $\boldsymbol{WiFi}$ - radio frequency module for data exchange with other agents; ***An*** - radio frequency module antenna; ***Pr*** - block of digital data processing (processor); ***ROM Instr*** - permanent memory of program code; ***RAM Knowledge*** - models of knowledge operational memory; ***Rg Act*** - a register for storing the code for the impact on the environment; ***y*** - output signal for environmental impact; ***D*** - data streams; ***I*** - information flows; ***C*** - streams of synchronization signals; ***P*** - flow of program code; $\boldsymbol{K}[\boldsymbol{T}-1]$ - knowledge models used to transform data and information; $\boldsymbol{K}[\boldsymbol{T}]$ - new models of knowledge obtained as a result of the analysis of information and old models of knowledge.

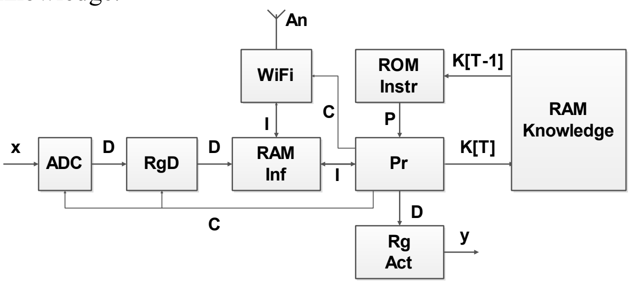

Figure 2. The functional model of the collective agent.

The process of the agent's transformation of data, information and adaptation of the knowledge model to the environment is presented in Figure 3, where: ***x*** - the state of the environment; ***s*** – the sensor; ***S / D*** - the process of converting an analog signal into a digital code; ***Data*** - the digital code (Data); ***D / I*** - the process of converting data into information describing the state of the environment; ***Information*** - information describing the state of the environment; ***I / K*** - the process of transforming information into knowledge; ***I / D*** - the process of converting information into solutions; ***Decision*** - decisions taken; ***A*** - environmental impact; $\boldsymbol{Knowledge}[\boldsymbol{T}-1]$ - knowledge models used to transform data and information; $\boldsymbol{Knowledge}[\boldsymbol{T}]$ - new models of knowledge obtained as a result of the analysis of information and old models of knowledge; $\Delta \boldsymbol{T}$ - time delay of new models of knowledge.

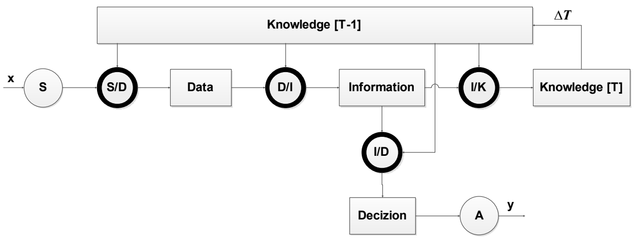

Figure 3. The process of data and information transformation by the agent.

IV. TPHE PROCESS OF INTERACTION OF AGENTS

The agent interaction process is presented in the form of a sequence diagram in Figure 4.

The sequence diagram contains a set of parallel functioning and interacting agents $\boldsymbol{Agent}\ \boldsymbol{i}, \forall \boldsymbol{i} = \overline{1, \boldsymbol{N}}$, each of them performs the following sequence of operations: $\boldsymbol{i}.1:[\boldsymbol{S}/\boldsymbol{D}]$- analog-to-digital conversion of the $\boldsymbol{x}$ input signal; $\boldsymbol{i}.2:[\boldsymbol{D}/\boldsymbol{I}]$ - transformation of data into information; $\boldsymbol{i}.3:[\boldsymbol{I}/\boldsymbol{D}]$ - decision-making; $\boldsymbol{i}.4:[\boldsymbol{A}]$ - environmental impact; $5:[\boldsymbol{TxD}/\boldsymbol{RxD}(\boldsymbol{I})]$ - information exchange between agents; $\boldsymbol{i}.6:[\boldsymbol{I}/\boldsymbol{K}]$ - calculation of a new knowledge model for the next cycle of calculations.

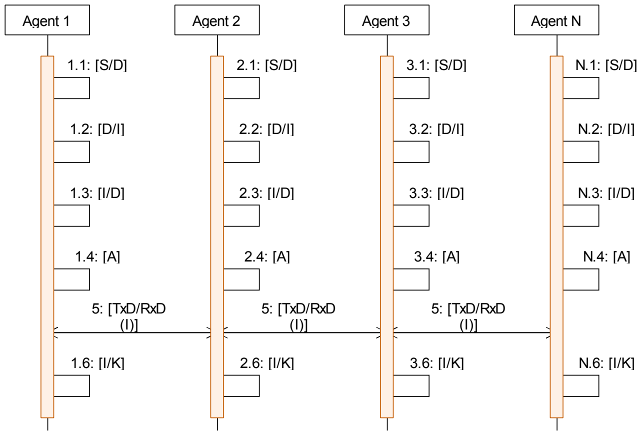

Figure 4. The process of agents interaction.

V. EXAMPLE OF ADAPTIVE DECISION-MAKING SYSTEM IMPLEMENTATION

For functional testing of the Multi-Agent Adaptive Decision System was selected the ***NodeMCU*** module [8], that is implemented based on the ESP8266-12E device [9], which provides the following specifications: 32-bit RISC CPU (Tensilica Xtensa LX106 running at 80 MHz); 64 KB of instruction RAM (***IRAM***); 96 KB of data RAM (***DRAM***); IEEE 802.11 b/g/n Wi-Fi; Integrated TCP/IP protocol stack; 16 GPIO pins; и 10-bit ADC.

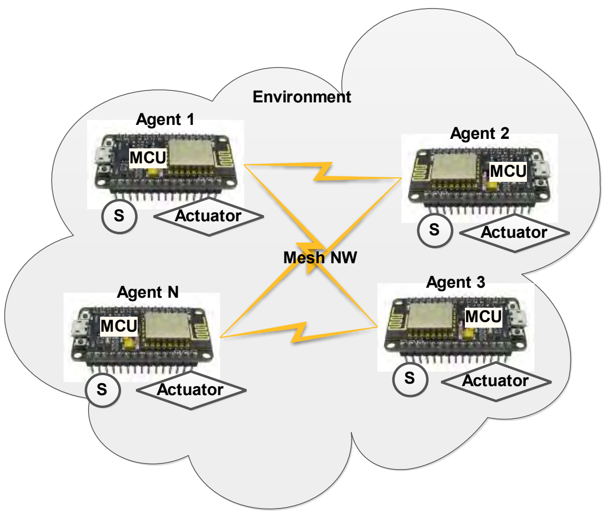

Figure 5. Example of the Multi-agent system implementation.

Figure 5 shows the structure of the Multi-Agent Adaptive Decision System, which consists of ***N*** agents ($\boldsymbol{Agent}\ \boldsymbol{i}, \forall \boldsymbol{i} = \overline{1, \boldsymbol{N}}$), that are forming a Mesh network

(***Mesh NW***). Each agent contains: ***MCU*** - NodeMCU module; ***S*** - sensor of environmental perception; ***Actuator*** - device to influence the environment.

The choice of NodeMCU (ESP8266-12E) modules [8, 9] for functional testing of the Multi-agent adaptive decision-making system is based on three conditions: minimum weight and power consumption, technical characteristics corresponding to the functional model of the collective agent (Figure 2) and support for data exchange in a Wi-Fi network.

VI. CONCLUSIONS AND SUGGESTIONS

As a result of the design of a collective agent for the synthesis of adaptive decision-making systems, the agent's functional model and the process of transforming data, information and knowledge to achieve the optimal value of the state of the environment were developed. A new model of knowledge is calculated as a result of an analysis of the state of the environment and the old model of knowledge. The process of interaction of agents is presented in the form of a sequence diagram. For functional testing of the collective agents' interaction, a computer network with a Mesh topology based on ***NodeMCU*** (ESP8266-12E) modules was implemented.

Further research involves simulating the behaviour of the Multi-agent system to detect conflicts during parallel processing of data and the implementation of the FPGA-based collective agent model.

REFERENCES

[1] L. Rodriguez, E. Insfran and L. Cernuzzi Requirements, "Modeling for Multi-Agent Systems," Multi-Agent Systems - Modeling, Control, Programming, Simulations and Applications, Dr. Faisal Alkhateeb (Ed.), InTech, DOI: 10.5772/14776, 2011. (Available at: https://www.intechopen.com/books/multi-agent-systems-modeling-control-programming-simulations-and-applications/requirements-modeling-for-multi-agent-systems).

[2] M. Guijarro, R. Fuentes-Fernández and G. Pajares "A Multi-Agent System Architecture for Sensor Networks," Multi-Agent Systems - Modeling, Control, Programming, Simulations and Applications, Dr. Faisal Alkhateeb (Ed.), InTech, DOI: 10.5772/14309, 2011. (Available at: https://www.intechopen.com/books/multi-agent-systems-modeling-control-programming-simulations-and-applications/a-multi-agent-system-architecture-for-sensor-networks).

[3] Y. Shoham, K. Leyton-Brown. Multiagent systems. Algorithmic, Game-Theoretic, and Logiacal Foundations. Published by Cambridge University Press. Revision 1.1, 2010. 532 p. (Available at: http://www.masfoundations.org).

[4] Чекинов, Г.П.; Чекинов, С.Г. "Применение технологии многоагентных систем для интеллектуальной поддержки принятия решения." Сетевой электронный научный журнал "СИСТЕМОТЕХНИКА", № 1, 2003 г. (Available at: http://systech.miem.edu.ru/2003/n1/Chekinov.htmg).

[5] Подубный, М., Сафонов Г., Негарэ, Е., Морошан И., Бордиан Д., Абабий В. "Система коллективного принятия решений для управления мобильными роботами." // Ежемесячный научный журнал "Евразийский Союз Ученых (ЕСУ)", 2016, № 6-2 (27), ISSN 2411-6467, С. 5-8.

[6] Абабий В. В., Судачевски В.М., Сафонов Г.И., Подубный М.В. "Многоагентная вычислительная система на базе мобильного программного кода вычислительного процесса." Альманах современной науки и образования, г. Тамбов: Грамота, 2016, № 9 (111), ISSN 1993-5552, pp. 10-14.

[7] Safonov Gh., Ababii V., Sudacevschi V. "Analysis of distributed computing architectures for synthesis of multi-agent systems." European Applied Sciences Journal, № 9, 2016 (September), ISSN 2195-2183, pp. 34-37.

[8] http://nodemcu.com/index_en.html.

[9] ESP8266 Datasheet. (Available at: http://espressif.com/sites/default/files/).