International Journal of Industrial Engineering & Production Research December 2020 Vol. 31, No. 4: 571-577
DOI: 10.22068/ijiepr.31.4.571

RESEARCH PAPER

Approach to Organizing the Functioning of Smart Elements in the Multi-Agent "Smart House" System

I. Shostak[1], Mariia Danova[2*], R. Melnyk[3] & O. Melnyk[4]

Received 8 August 2020; Revised 8 September 2020; Accepted 18 October 2020; Published online 30 October 2020

ABSTRACT

A research was conducted to form an approach to the design and implementation of a multi-agent control system of smart elements for a "Smart house". The system was built on the example of three intelligent robots. In the architecture of the system under development, the main part is the subject-independent multi-agent kernel, which includes the following basic components: direct access service, the messaging service, agent class library, agent community, ontology. It was found that the multi-agent approach using ontologies in the framework of this problem significantly exceeds traditional methods in efficiency. The experimental part includes a description of scenarios for organizing the functioning of smart elements in a multi-agent system. This system simulates the adaptive, remote and almost independent functioning of the intelligent objects of the "Smart House". The developed scenarios have shown the feasibility of applying this approach for a wide class of objects, such as a "Smart house".

KEYWORDS: *Smart house; Multi-agent system; Smart elements; Ontologies; Intelligent objects.*

1. Introduction

Today, the issue of creating intelligent systems (IS) in certain areas of science and industry is very relevant, which could greatly simplify the search and access to the necessary (relevant) information for engineers and scientists in huge storage facilities. The construction and implementation of intelligent systems based on the formalization and reuse of knowledge is a promising direction in the practical application of artificial intelligence methods in software systems [1, 2]. The basis of such systems is a formalized representation of knowledge about the subject area, for example, in the form of ontology [3]. The definition of ontology by Gruber as a specification of a certain conceptualization leaves open the question of choosing a formal apparatus and language tools for constructing such a specification. Unresolved are the tasks of analyzing and identifying the essence of the ontological description of the domain, determining its inherent limitations and advantages. This requires the construction and study of formal models for various aspects of ontological modeling [4].

The architecture of modern IS is based on ontologies formed for a given subject area. In the process of implementing IS, the stage of the initial formation of such an ontology and its further filling with new knowledge is difficult. In modern conditions of increasing the complexity of information and the process of its processing, a situation more and more often arises in which not only a person, but even an algorithmic method of processing become ineffective. These situations require flexible processing methods. One of these methods is the method of constructing multi-agent systems [5, 6].

Work management systems are a good example of the use of intelligent agents. Works can have a wide range of artificial sensory organs (sensory elements) and artificial effectors (manipulators, pedipulators). We are talking about robotic devices that perform tasks associated with movements in space. The activity and autonomy of robots are closely related to the availability of

* Corresponding author: ***Mariia Danova***
danovamariya@gmail.com

1. *Department of Software Engineering, Faculty of Software Engineering and Business, National Aerospace University, "Kharkiv Aviation Institute", Kharkiv, Ukraine.*
2. *Department of Software Engineering, Faculty of Software Engineering and Business, National Aerospace University, "Kharkiv Aviation Institute", Kharkiv, Ukraine.*
3. *Department of automatic safety systems and electrical Installations, National University of Civil Defence of Ukraine, Kharkiv, Ukraine*
4. *Department of safety of construction and labor protection, National University of Civil Defence of Ukraine, Kharkiv, Ukraine.*

action planning tools, task solution support systems, and intellectualization, in addition to owning a knowledge processing system, involves developed communication tools of various levels, up to natural language communication tools [5, 7].

An integral attribute of intelligent robots is the presence of a special planning subsystem that makes up the program of action in real environmental conditions, which are determined by the sensors of the robot. To plan activities, the robot must have knowledge of the properties of the environment and the ways to achieve goals in this environment [8].

The aim of the article is to describe the approach to creating a multi-agent object management system "Smart Home", based on the use of ontological engineering and multi-agent technology.

2. Materials and Methods

The main task is to build a multi-agent system for intelligent robots and incorporate ontologies in their architecture, for adaptive interaction with each other [9, 10].

In the architecture of the system under development, the main part is the subject-independent multi-agent kernel, which includes the following basic components (Fig. 1):

1. Direct access service provides direct access of the visual part to the attributes of agents. At the same time, the visual part can communicate with agents using messages, but the use of this subsystem is, firstly, faster, and secondly, has more opportunities for operating agents.
2. The messaging service is responsible for transferring messages both between agents and between agents and additional kernel systems.
3. Agent class library is part of the knowledge base that contains information about what types of agents are used as part of IS. To increase the flexibility of the system, the information in this directory can be supplemented with external extensions through the interface.
4. Agent community - a place where agents are located. This block, in addition to the vital activity of agents, also provides functions for loading / writing agents and their properties and for optimizing work with resources.
5. Ontology is a subject knowledge base containing specific knowledge about a subject (logistics), which are presented in the form of a semantic network.

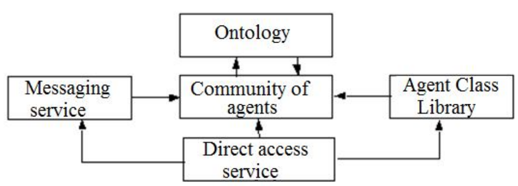

Fig. 1. Architecture of the multi-agent system kernel

When an agent is developed, it is necessary, first, to determine the area of technological activity of the agent and the methods that are provided as part of this activity [11]. These definitions should be described in a single unique form for the system, which is an "ontological description": [Field of knowledge] / [Field of technological activity] / [Section of technological activity] / [Action] / [Option].

In order for the developer to be able to uniquely correctly describe the activities of the agent, he selects the sections in the description from those provided by the parent class [12]. The ontological description for an individual agent is specified for each method that the agent provides [13].

The ontological parent class must include the maximum possible description of the "world", so that the developer can choose the description for the agent method that is the only correct one [14]. Also, the parent class must provide data for each section of the "ontological description" so that there is no confusion in the assembly order. When an agent connects to the system, it passes its ontological descriptions to the server [15].

In Fig. 2, we consider the main actions of the agents and the server agent (hereinafter referred to as the server) related to the ontology. First of all, the interaction of agents, most likely, begins with an "ontological request" to the server. The ontological request is an "ontological description", only directed to the server [16]. After that, the server, in its knowledge base, checks the "ontological descriptions" available in it with the received "ontological request" and, if it finds a match, gives the agent parameters and the address of the agent / request method. After that, the agent who sent the request sends a request to the agent, with the data in the form of a structure containing parameters. The responsible agent also transmits data in the form of a special structure for the response.

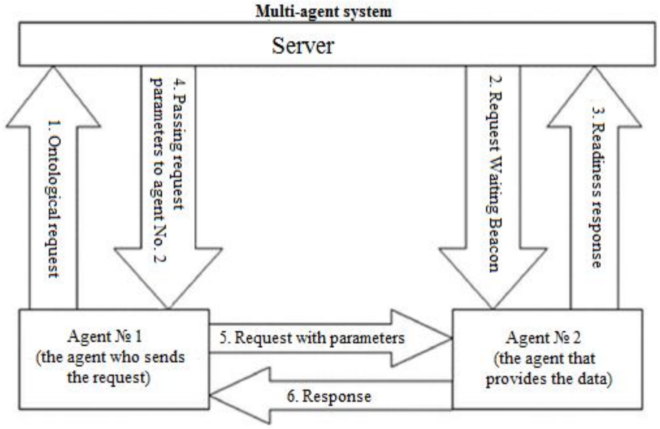

Fig. 2. A diagram of the agents interaction in a multi-agent system

Run Time Multi-Agent Execution System - a subsystem that provides asynchronous execution of agent programs upon transition from one state to another (agent manager) and message passing between agents, in which the agent receives a "quantum" of time for event processing and then returns control to the dispatcher for promotion the following agents, that is, agents work synchronously. Part of this system is the Agent Inspector and Agent Log (agent conversation log), showing all messages between them (Fig. 3).

In Fig. 4 shows the class diagram used in the created multi-agent system.

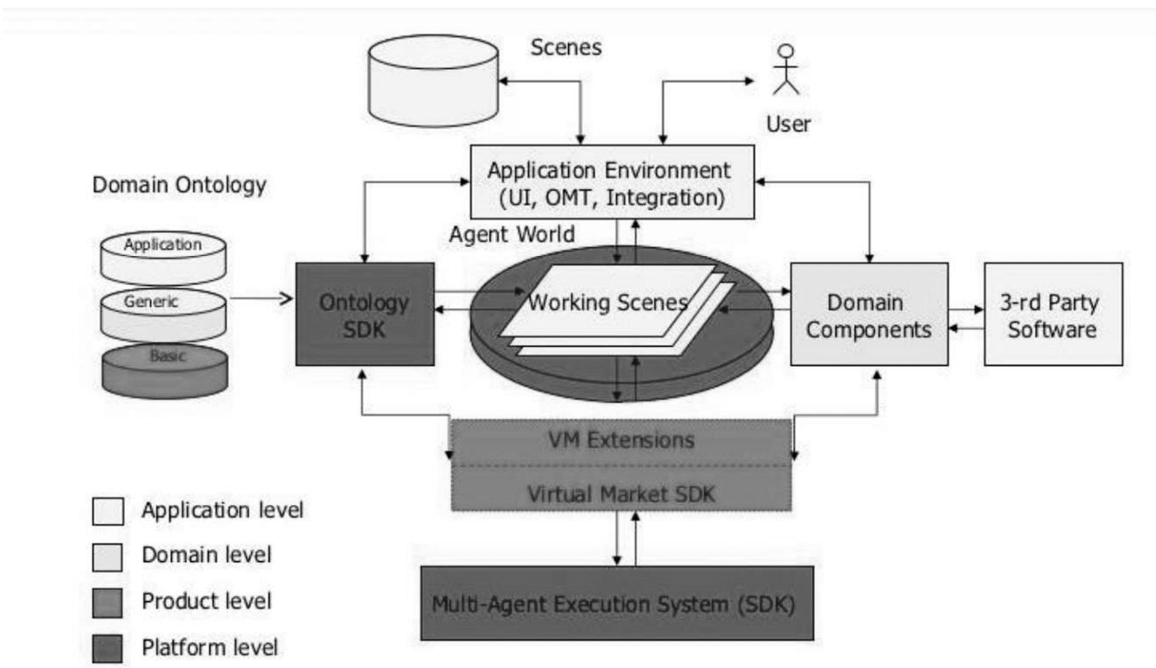

Fig. 3. The structure of the adaptive planning module

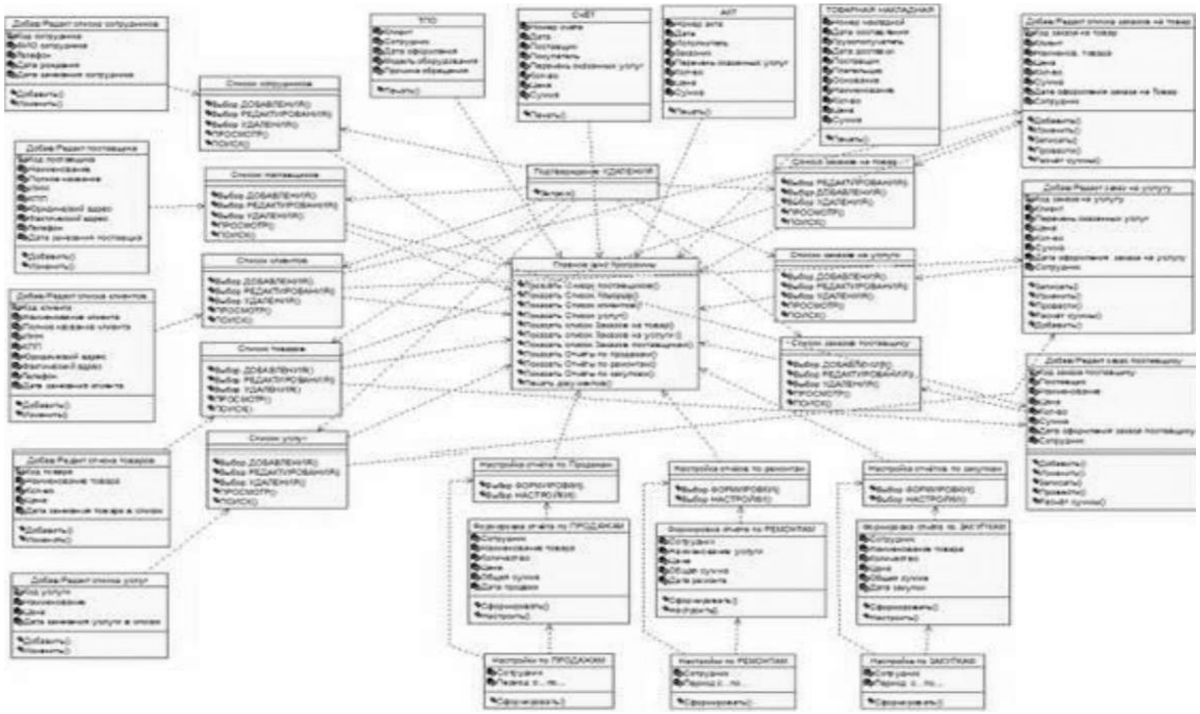

Fig. 4. UML Class Diagram

3. Results and Discussion

For example, three smart devices were taken: a vacuum cleaner (hereinafter Agent A), a refrigerator (hereinafter Agent B) and a television (hereinafter Agent C). Since each of the selected objects has several functions, we can say that they are not just agents, but an organization of agents. Schematically, such a multi-agent system is shown in Fig. 5 - 7.

To test the implementation of ontology as a knowledge base of a multi-magnet system of smart robots, several scenarios were developed.

3.1. Scenario #1

Now a very important problem for smart vacuum cleaners is that they try to clean objects that cannot be cleaned with their help, because the situation is only getting worse, and you need to apply wet cleaning both for the floor surface and for the vacuum cleaner itself. For such situations, it was decided to add the opportunity to learn to the functionality. So suppose that the vacuum cleaner received a request to clean an object of incomprehensible consistency.

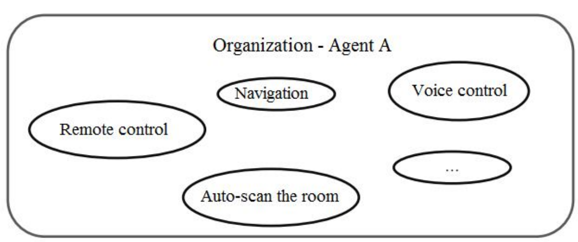

Fig. 5. Agent A, organization of internal agent-functions

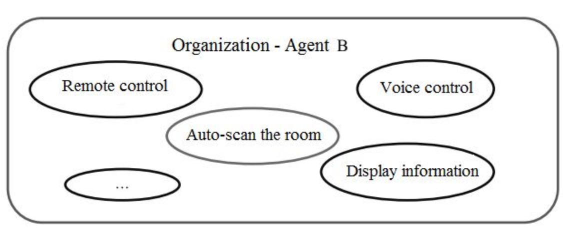

Fig. 6. Agent B, organization of internal agent-functions

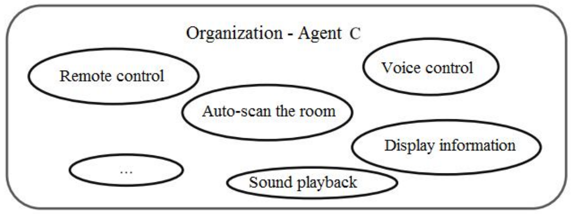

Fig. 7. Agent C, organization of internal agent-functions

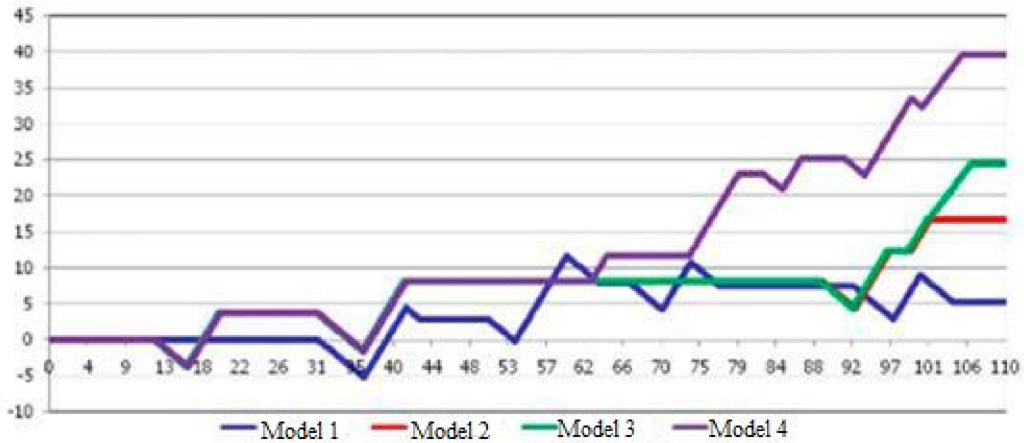

Fig. 8. Graph showing the estimated time savings of using smart robots

4. Conclusion

The article sets out an approach to designing and implementing a multi-agent smart home control system for the Smart Home, and conducted scenario experiments on them.

It was found that the multi-agent approach using the ontologies of the selected problem significantly exceeds traditional methods in efficiency, since it allows you to take into account a much larger number of factors, increases the adaptability of such a system and reduces the time it takes the user to work with it.

This system simulates the adaptive, remote and almost independent operation of the intelligent objects of the Smart Home. The experimental part showed a significant right to the existence of such a system, as well as a significant advantage over others. Compared with other types of control, as can be seen from Fig. 8, with the help of model 4, the time savings increased by 40-60%, and in the future it can be an even larger percentage. This proves the significant advantage of the adaptive control model over others. The developed scenarios provided not only a way to solve some problems, but also showed ways of future development of the system and its application on large-scale examples.

Another important conclusion is that voice control involves specific phrases and in a specific language, which are embedded in each object. This is not always convenient, therefore it will be advisable to further develop the system in the direction of applying acts of speech. This will definitely make it easier for the user to work with such a system from the very first steps, and the system will become more flexible and even more adaptive.

References

[1] Eivazzadeh, S., Anderberg, P., Larsson, T.C., Fricker, S.A., Berglund, J. *"Evaluating Health Information Systems Using Ontologies"*, JMIR Med Inform, No. Vol. 4, No. 2, e20, (2016), pp. 1-13 .

[2] Fensel, D., Mcguinness, D., Schulten, E., Ng, W. K., Lim, E., Yan, G. *"Ontologies and Electronic Commerce"*, IEEE Intelligent Systems, Vol. 16, (2001), pp. 8-14.

[3] Lavbic, D., Vasilecas, O., Rupnik, R. *"Ontology-based multi-agent system to support business users and management"*, Technological and Economic Development of Economy (TEDE), Vol. 16, No. 2, (2010), pp. 327 - 347.

[4] Hayes. P., Horrocks. I., Patel-Schneider. P.F. (Eds.), OWL - Web Ontology Language

Semantics and Abstract Syntax, W3C Recommendation, (2004).

[5] Shostak, I., Kapitan, R., Volobuyeva, L., Danova, M., *"Ontological Approach to the Construction of Multi-Agent Systems for the Maintenance Supporting Processes of Production Equipment*", In Proc.: IEEE International Scientific and Practical Conference «Problems of Infocommunications. Science and Technology» (PICS&T-2018), Ukraine, Kharkiv, (2018), pp. 209 -214.

[6] Gontareva, I., Babenko, V., Shmatko, N., Litvinov, O., Hanna, O. The Model of Network Consulting Communication at the Early Stages of Entrepreneurship. *WSEAS Transactions on Environment and Development*, Vol. 16, (2020), pp. 390-396. DOI: https://doi.org/10.37394/232015.2020.16.39

[7] Bezgubova, Y.O., *"Modeli programmnykh agentov v zadachakh informatsionnogo poiska"* [Models of software agents in information retrieval tasks], Slavyanskiy forum, No. Vol. 2, No. 8, (2015), pp. 41-49 [in Russian].

[8] Gontareva, I., Maryna, B., Babenko, V., Perevozova, I., Mokhnenko, A. Identification of efficiency factors for control over information and communication provision of sustainable development in higher education institutions. *WSEAS Transactions on Environment and Development*. Vol. 15, (2019), pp. 593-604.

[9] Freitas, A., Bordini, R.H., Vieira, R., Designing Multi-Agent Systems from Ontology Models. In: Weyns D., Mascardi V., Ricci A. (eds) Engineering Multi-Agent Systems: Lecture Notes in Computer Science, (2019), pp. 11375.

[10] Dignum, V., Dignum, F., Modelling agent societies: co-ordination frameworks and institutions, In: Brazdil P., Jorge A. (eds.) Progress in Artificial Intelligence: Knowledge Extraction, Multi-agent Systems, Logic Programming, and Constraint Solving, (2001), pp. 191-204.

[11] Bellifemine, F., Caire, G., Trucco, T., Rimassa, G., JADE Programmer's Guide, Italy, CSELT SpA, (2000).

[12] Bellifemine, F., Caire, G., Greenwood, D., Developing Multi- Agent Systems with JADE, John Wiley & Sons Ltd, (2007).

[13] Reshetnyak, O. Research of the status of scientific and technical development of the countries of the world. *The Journal of V. N. Karazin Kharkiv National University. Series: International Relations. Economics. Country Studies. Tourism*, No. 10, (2020), pp. 41-51. https://doi.org/10.26565/2310-9513-2019-10-04

[14] Kuznetsov, A., Lutsenko, M., Kuznetsova, K., Martyniuk, O., Babenko, V., Perevozova, I. Statistical Testing of Blockchain Hash Algorithms. *CEUR Workshop Proceedings*, Vol. 2588, (2019), pp. 67-79. Online, http://ceur-ws.org/Vol-2393/. URL: http://ceur-ws.org/Vol-2588/paper7.pdf

[15] Caporale, G.M., Plastun, A., Oliinyk, V. Bitcoin fluctuations and the frequency of price overreactions. *Financial Markets and Portfolio Management*. Vol. 33, No. 2, (2019), pp. 109-131. https://doi.org/10.1007/s11408-019-00332-5

[16] Halynska, Y., Oliinyk, V. Modeling of the Distribution Mechanism for Fuel Industry Enterprises' Rental Income in the System. State – Region – Enterprise. *Journal of Advanced Research in Law and Economics*, Vol. 11, 2(48), (2020), pp. 370-381. doi: https://doi.org/10.14505/jarle.v11.2(48).10.

[17] Bila, O., Gontareva, I., Babenko, V., Kovalenko, O., Gliebova, N. Organizational and Methodological Guidelines for Training Education Managers to Implement the Strategy of Corporate Social Responsibility. *2019 3rd European Conference on Electrical Engineering and Computer Science (EECS)*, (2019), pp. 140-146. DOI: 10.1109/EECS49779.2019.00037

[18] Tromp, J.G., Le, D.-N., Van Le, C. and Babenko, V. (2020). Enterprise Innovation Management in Industry 4.0. In Emerging Extended Reality Technologies for Industry 4.0 (eds J.G. Tromp, D.-N. Le and C. Le). doi:10.1002/9781119654674.ch9

[19] Babenko, V.O., Yatsenko, R.M., Migunov, P.D., Salem, A.-B.M. MarkHub Cloud Online Editor as a modern web-based book creation tool.

CEUR Workshop Proceedings. Vol. 2643, (2020), pp. 174-184. URL: http://ceur-ws.org/Vol-2643/paper09.pdf.

[20] Babenko, V.O., Yatsenko, R.M., Migunov, P.D., Salem, A.-B.M. MarkHub Cloud Online Editor as a modern web-based book creation tool. *CEUR Workshop Proceedings*. Vol. 2643, (2020), pp. 174-184. URL: http://ceur-ws.org/Vol-2643/paper09.pdf

Follow This Article at The Following Site:

Shostak I, Danova M, Melnyk R, Melnyk O. Approach to Organizing the Functioning of Smart Elements in the Multi-Agent "Smart House" System. IJIEPR. 2020; 31 (4) :571-577
URL: http://ijiepr.iust.ac.ir/article-1-1131-en.html