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THE USE OF COGNITIVE AGENT PROGRAMS IN MANAGEMENT SUPPORT

WYKORZYSTANIE KOGNITYWNYCH PROGRAMÓW AGENTOWYCH WE WSPOMAGANIU ZARZĄDZANIA

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Abstract: A modern economy, based on information and knowledge, forces organizations to use IT tools that support management processes. The authors presented the concept of using cognitive agent programs to support management. These programs are able to track economic phenomena and processes taking place in the organization and its environment, conduct an in-depth analysis of information, draw conclusions and take specific actions. The features of cognitive agents allow organizations to gain a competitive advantage by making the right decisions faster at the operational, tactical and strategic level and by limiting the impact of such human characteristics as emotions or fatigue on task execution. The first part of the article outlines a characterisation of cognitive agent programs. The management areas in which cognitive agents can be used are then analysed and presented. The final part of the article provides conclusions and further research work.

Keywords: cognitive agents, decision support, agent learning, use of cognitive agents.

Streszczenie: Nowoczesna gospodarka, oparta na informacji i wiedzy, zmusza organizacje do korzystania z narzędzi informatycznych, które wspierają procesy zarządzania. Autorzy przedstawili koncepcję wykorzystania kognitywnych programów agentowych do wspomagania zarządzania. Programy te potrafią śledzić zjawiska i procesy ekonomiczne zachodzące w organizacji oraz w jej otoczeniu, prowadzić dogłębną analizę informacji, wyciągać wnioski i podejmować konkretne działania. Cechy agentów kognitywnych pozwalają organizacjom na uzyskanie przewagi konkurencyjnej dzięki szybszemu podejmowaniu trafnych decyzji na poziomie operacyjnym, taktycznym i strategicznym oraz ograniczeniu wpływu takich cech ludzkich, jak emocje lub zmęczenie, na realizację zadań. W pierwszej części artykułu przedstawiono charakterystykę kognitywnych programów agentowych. Następnie przeanalizowano i zaprezentowano obszary zarządzania, w których mogą one być wykorzystywane. Ostatnia część artykułu zawiera wnioski i kierunki dalszych prac badawczych.

Słowa kluczowe: agenty kognitywne, wspomaganie decyzji, uczenie się agentów, zastosowanie agentów kognitywnych.

1. Introduction

Information technologies play a very important role in the operation of businesses, being one of the most important solutions making it possible to gain a competitive advantage. They allow a large amount of information to be collected, processed, and transmitted, also enabling to draw conclusions from this information, thus contributing to the creation of organisations' knowledge. However, these characteristics are no longer sufficient. There is a growing need to make decisions based not only on knowledge but also on experience, which until now has been treated as a human domain (Duch, 2010; Fan, McNeese, and Yen, 2010). Given the great turbulency of the economic environment and the need for near-real-time decision-making, IT technologies applied in management support should be equipped with functions for automatic analysis of the real significance of the business phenomena and processes observed as well as of decision-making, especially at tactical and operational levels. To perform these functions, cognitive agent programs (cognitive agents) (Franklin, 2006) can be employed. Not only do they enable easy access to information and

a quick search of the information of interest, as well as analysing and drawing conclusions from it, but also, in addition to reacting to environmental stimuli, they have cognitive abilities that allow learning through empirical experience gained via direct interaction with the environment (Duch, 2010), which consequently makes it possible to automatically generate decision variants and in many cases, even make and implement decisions (Chen, Liu, and Williams, 2009).

As far as cognitive agents are concerned, a breakthrough was the paper by Bratman (1988), discussing the behaviour of a rational (human) subject in mental and cognitive terms such as beliefs, desires, and intentions (BDI). Since then, he and other scholars have tried to gain a better understanding of cognitive concepts by trying to formalize them by using some logical frameworks or inventing an architecture for intelligent agents (Wooldridge, 2000; Gkiokas and Cristea, 2018).

Deloitte refers to cognitive computing as more encompassing than the traditional, narrow view of AI, and looks at cognitive computing as being defined by machine intelligence, which is a collection of algorithmic capabilities that can augment employee performance, automate increasingly complex workloads, and develop cognitive agents that simulate both human thinking and engagement (Davenport, 2016).

The purpose of this article is to analyse the possibility of using cognitive agent programs in management support. The first part of the article outlines a characterisation of cognitive agent programs. The management areas in which cognitive agents can be used are then analysed and presented. The final section provides conclusions and further research work. This article seeks to fill a gap in the available literature on the use of these agents in the field of management.

2. Cognitive agent programs

The term 'cognitive agent' (cognitive agent program) is defined in different ways in the literature, but according to the most common definition, this kind of agent is a computer program which (Sathish and Venkataram, 2008):

- is capable of taking action in the environment in which it is located,
- can communicate directly with other agents,
- is guided by a set of habits and tendencies that are either specific objectives or an optimized function of benefits,
- has its own resources,
- is capable of receiving stimuli from its surroundings but to a limited extent,
- may have knowledge of this environment,
- has skills and can offer services,
- can reproduce or clone itself,
- is characterized by a behaviour driving it to pursue objectives, taking into account available knowledge, resources, and skills and relying on its ability to perceive stimuli from its environment and communicate,
- can acquire knowledge of the environment and learn by gaining experience.

Therefore it can be said that a cognitive agent is an intelligent program which not only draws conclusions based on the data it receives, takes specific actions to achieve a set objective (e.g. decision support), but also, unlike a reactive agent program, learns and gains experience at the same time. The differences between cognitive and reactive agents are presented in Table 1.

Table 1. A comparison between a cognitive and a reactive agent

Cognitive agent	Reactive agent
• inference based on logic, ontologies, and knowledge, • higher maintenance costs, • self-sufficiency, • actions initiated by environmental stimuli, • cognitive skills, • learning.	• inference based on the state of the sensory inputs, • low maintenance costs, • lack of self-sufficiency, • actions depending on specific situations, • lack of cognitive skills, • operation on the basis of programmed methods with no learning capabilities.

Source: own work.

It should be noted that a cognitive agent is self-sufficient, i.e. it can make decisions on its own, without human involvement (such agents are used, for example, in devices operating in space).

The higher costs of maintaining a cognitive agent are primarily related to the higher demand for IT resources (hardware, software, and data resources).

In the construction of cognitive agents, a mixed, symbolic-connectionist organisation of memory is mostly used, which aims at consolidating the meanings of all symbols. Consolidation is understood as the action of the cognitive processes responsible for establishing and maintaining the relationship between language signs and the corresponding objects of the world. One of the most common definitions of consolidation assumes that it is carried out by three specialized sub-processes: iconisation – transforming analogue signals coming from external world objects into their internal analogue equivalents; differentiation – determining whether two inputs received by the agent's sensors come from identical or different objects; identification – assigning unique names to a class of inputs that are analogous or in some respect indistinguishable (Kataryniak, 2007).

Various solutions for building an internal agent program are found in the literature on the subject. One such solution, proposed by Franklin (Franklin, 2006), is shown in Figure 1. According to the solution's premise, the cognitive agent consists of the following modules:

- working memory,
- global working memory,
- sensory memory,

- perceptual memory,
- episodic memory,
- declaratory memory,
- sensory-motor memory,
- selection of activities,
- current awareness.

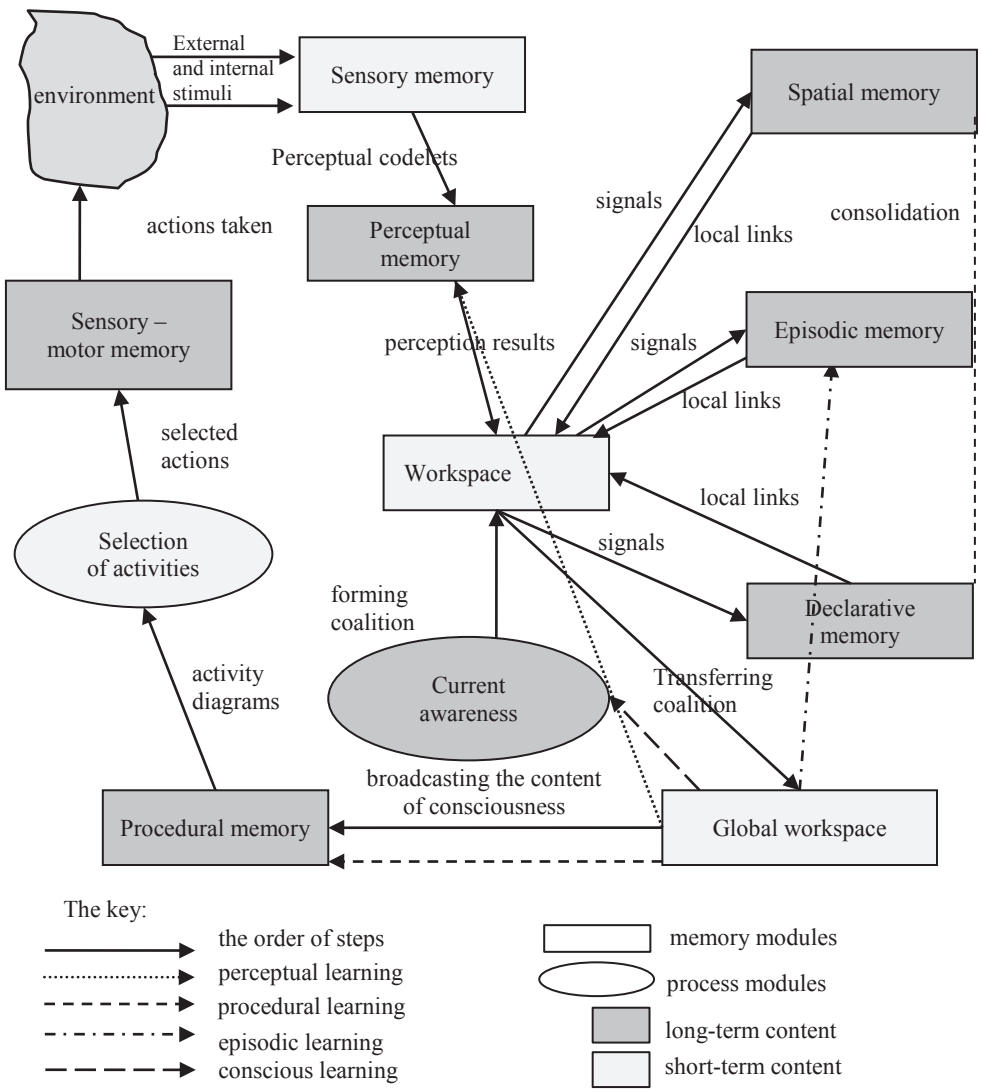

Fig. 1. A cognitive agent's structure and operation – a simplified diagram

Source: own work.

Most of the basic, simple operations are performed by so-called codelets, i.e. specialized fragments of the neural network that act as unconscious processors processing information in the global working memory model (Cognitive, 2020). Codelets are implemented in the shape of short programs (functions) with a few lines of code; then, these programs are executed, i.e. they operate in the form of mobile processes 'carrying' the necessary information in the agent's internal network. After completing the task, codelets end their activity (the process ends).

The operation of a cognitive agent is divided into three phases: understanding, awareness, and selecting actions and learning (Hernes, 2019). At the beginning of the understanding phase, the stimuli received from the environment activate the codelets of low-level characteristics in the sensory memory.

These codelets' outputs activate the perceptual memory, where the codelets of high-level characteristics feed more abstract instances such as objects, categories, actions, or events. The perception results are transferred to the working memory and, based on the episodic and declarative memory, local links are created and then, using the perceptual memory instances, the current situation model is generated, in other words, the agent understands what phenomena are occurring in the environment (Madl, Baars, and Franklin, 2011). The awareness phase begins with the formation of coalitions of the situation model's most important elements, which then compete for attention, i.e. the place in the content of the current awareness. This current content is then 'broadcast' (i.e. transferred to the global working memory), at the same time initiating the phase of selecting actions and learning (Franklin, 2006). In this phase, possible action schemes are taken from the procedural memory and sent to the action selection module where they compete for selection in this cycle. The selected actions trigger the sensory-motor memory to create a relevant algorithm to execute them, which is the final stage of the cognitive cycle (Hernes, 2019).

The agent's learning (carried out in parallel with the previous activities) takes the form of perceptual, episodic, procedural, and conscious learning and is controlled from the bottom up, i.e. it starts when stimuli from the environment are received.

Perceptual learning concerns recognizing new objects, categories, and relationships, and is based either on changing the strength of synaptic connections between nodes or creating new nodes and connections in the perceptual memory.

Episodic learning means remembering specific events – what, where, and when – appearing in the working memory and therefore available in the consciousness. **Procedural learning**, namely learning new actions and sequences of actions needed to solve the problems posed, carried out in two ways. The first is the selection of activities from the known repertoire, and the second is the construction of new representations for action sequences by means of learning with a critic[9]. **Conscious learning** refers to the learning of new modes of conscious behaviour or the reinforcement of existing conscious behaviour, which occurs when an element of the situational model is often located in the current awareness module (Hernes, 2019).

[9] A critic can be a person, or a computer program that confirms the correctness of the cognitive agent's learning.

3. Examples of using cognitive agents in management support

It is now becoming necessary for companies to have quick access to information and to quickly find the information one is interested in, as well as analyse it, draw conclusions, and make a quick and accurate decision. These activities may be performed by cognitive agent programs.

Cognitive agents can perform the following functions:

- Monitoring phenomena taking place in the company's environment (which is also the environment in which agents operate) and obtaining information. This function consists in reading, on an ongoing basis, information from the Internet and mobile devices, as well as information provided by the company's employees and received from other agent programs operating in the system.
- Processing and inference. Based on the information obtained, the agent carries out the inference process.
- Decision-making. The agent program makes decisions on the basis of conclusions and implements them or forwards them to other agents for implementation.
- Process control. It is not uncommon for cognitive agents to be able to gather more information than traditional control systems, as mentioned in item 1. This ability allows them to influence processes in such a way that their results are as beneficial as possible. It is noteworthy that it does not have to be one category (e.g. profit), but many different ones (e.g. both profit, environmental protection, impact on the company's environment, etc.).
- Detecting future delays. Cognitive agents who have access to information about the condition of machinery in the company can predict when (roughly) it will break down. If the sensors are properly set up, the system will be able to figure the probability of exactly what part will fail and when it will happen. Therefore, the system will send out a message that the item in question must be replaced. This will save the time that would normally be spent removing the effects of the defect and replacing the damaged part.
- Obtaining information on currency exchange rates in different markets from the Internet and monitoring the most advantageous purchase or sales offers.
- Monitoring the situation on world stock exchanges and searching for favourable purchase offers, as well as reporting on the need to sell off assets that are losing value.
- Customer relationships management. It is enough for a company to develop the objectives and results of the marketing campaign in its CRM system, and the agent program will select the customer segments on its own and choose the actions to carry out as part of the campaign from the company's catalogue of activities (based on historical data) to achieve the assumed results.
- Analysis and prediction of customer behaviour based on programs collecting information about the customer from various sources such as social networking sites, WhatsApp, the Internet of Things, etc. Cognitive agents can also create

tailored messages and use such solutions to influence customer preferences and decisions. It is also worth looking at the segment of so-called intelligent assistants. Agent programs, using the data provided to them, process data intelligently, carry out an inference process, and then suggest actions and even perform certain actions on their own, thus relieving the user. It should be stressed that these programs learn independently and continuously during operation.

- Detecting models and patterns of behaviour of both customers and suppliers. By processing a very large amount of data (number of orders, ratio of returns and complaints, current and historical stock levels, discrepancies, task completion time) generated in different systems, cognitive agents obtain information about which goods are most frequently ordered, which are most often picked together and on which days of the week, etc. They can also determine, in real-time, the availability of products ordered by customers, taking into account many aspects that are not very predictable from the point of view of the company, such as the weather or traffic jams. They also predict the date and time of receiving an order which the customer has not yet placed. This information is used in areas including the production planning process, logistics, and the distribution and picking of goods in the warehouse. It is quite likely that, in the near future, the agent system will be able to generate orders itself and have them prepared for fulfilment to even out and standardize the workload at logistics centres by analysing previous situations and examples.
- Cognitive agents can quickly interpret and process unstructured data, e.g. e-mails, using natural language analysis tools, among others. They can support data collection within the company by supplementing or completely replacing traditional information collection systems, which in turn provides an opportunity to support the company's administration and management.
- The interpretation of text and speech as well as the ability to interpret contexts and situations make it possible for cognitive agents to improve communication with the customer and speed up services. An intelligent chat based on cognitive agents is capable of asking precise questions, recognizing situations, and then remembering and saving information faster and more accurately than a consultant or a manually filled out form.
- Cognitive agents are becoming particularly important in situations where there is very little time to make decisions or where many decisions must be made at the same time. This is particularly frequently seen in manufacturing companies, where even short machinery downtimes caused by disruptions to manufacturing processes, can generate large losses. Commonly used automatic control systems are based on predefined operating patterns. Systems based on cognitive agents enable quick decisions to be made even in non-standard situations, e.g. during unforeseen equipment failures.
- The perceptual module, based on a properly defined ontology, can not only identify familiar situations but also recognize new events. Using defined

relationships between objects, it can also characterize the impact of new events on existing processes. A structure of entities defined in such a way has great potential in recognizing environmental opportunities and threats for the company.

- Cognitive agents can identify patterns of attacks and anomalies in the operation of company systems. They are resistant to fatigue or haste, which are very often taken advantage of in social engineering attacks. Agents can continuously monitor all the company's subnets and systems, enabling them to respond to attacks in real-time.

Thus it can be said that cognitive agents are beginning to replace humans, performing many activities for them, especially routine tasks related to their work. This will allow the employee to devote more time to the development-oriented work for the company, hence they will not have to devote their free time to professional matters (as during this time, an agent will work for them), thanks to which the level of fatigue and stress connected with work will be reduced, which will also have a positive impact on the company's growth.

4. Conclusion

The development of information technologies has led to companies implementing business processes more effectively. Business activity can be carried out on global markets without time constraints. However at present, the integration of business processes, support for knowledge management processes, and decision support provided by means of these technologies, is insufficient. One of the important tasks is to automatically support the activities so far carried out in enterprises by people, starting from tasks performed at workstations, through the diagnosis of the current economic situation, to automatic decision-making, particularly at operational and tactical levels, and to suggest decisions taken at strategic level. This is related to the ability to correctly interpret and associate facts, discovering links between objects and phenomena of the real world, as well as learning and having experience. Cognitive agent programs can be used to carry out such management support tasks. Obviously, the ideal operation of cognitive agents cannot be guaranteed, because artificial intelligence has not yet developed solutions that can fully replace the functions of the human mind, but only the use of these agents in a practical environment will allow the continuous improvement of their capabilities and skills. Another problem is the use of the appropriate executive elements in the system (an agent program cannot, for example, physically operate a lathe – it has to do so using proper grippers), which raises many issues concerning their control.

Despite these inconveniences the use of cognitive agents becomes indispensable mainly due to companies seeing opportunities of gaining a competitive advantage as a result of limiting the influence of such human characteristics as emotions or fatigue

on the performance of professional tasks, the need to reduce the burden of information flows on people, and the reduction of their work without having rest.

Further research may include the development of prototypes of cognitive agent programs to support specific management areas.

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