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## SOURCES OF KNOWLEDGE CONFLICTS IN COGNITIVE AGENT'S ARCHITECTURE IN DSS<sup>1</sup>

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**Abstract:** This paper presents the problem of knowledge conflicts identification in the architecture of cognitive agents. The agents operate at the decision support systems. The types and the sample of cognitive agents architecture was characterized in the first part of article. Next, the customer relationship management agent was described and the causes of knowledge conflicts were indicated. The final part of article contains the analysis of sources of knowledge conflicts and their examples related to decision-making process.

**Keywords:** Knowledge conflicts, cognitive agents, decision support systems.

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### 1. Introduction

Decision support systems (DSS) play nowadays very important role in different types of organization functionalizing. Often they are developed in form of multi-agent systems, and consist of certain number of software agents. It is necessary to underline that taking decision is a very important element of organization functioning at the market and it is related with many problems. Markets are very turbulent. Decision-makers have to make fast and correct decisions. So it is necessary to use DSS. They can find information about the proper value [Sobieska-Karpińska, Hernes 2013] and conclude the base for this information. This system reads suitable data needed for decision-making. They also allow for solving a problem quickly. Currently used DSS are the support mainly at an operational and tactical levels but they become insufficient at a strategic level. DSS only enable the analysis – the form of information, the links between economic values and these systems are unable of the analysis of the meaning of information. Thus these tools mainly serve for the conversion of the gathered data (mostly disordered and unstructured) into information – useful, legible and easily interpretable and thus more suitable to a decision-maker. However, for the

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<sup>1</sup> Selected parts of this article were published under nonexclusive copyright in Proceedings of the Federated Conference on Computer Science and Information Systems FedCSIS 2014 (see [Sobieska-Karpińska, Hernes 2014]).

definition of meaning of information, a human mind is necessary, and the change of knowledge into wisdom (necessary to take a good decision) requires not only human intellect but even human genius [Tadeusiewicz 2013]. Therefore, it seems justified to use the tools (technologies) which perform cognitive and decision-making functions, the ones that take place in the human brain and owing to this are capable of understanding the real meaning of the observed phenomena and economic processes taking place in the organization environment. These tools include cognitive agents which often cooperate within the framework of a multi-agent system [Żytniewski et al. 2013] in order to effectively reach a set goal.

The architectures of cognitive agents are complex and their functioning is of asynchronous nature, which may be the reason for the occurrence of knowledge conflicts and have a negative impact on the results of cognitive and decision-making functions, which in turn may hinder supporting a decision-making process.

Previous research related to the issues of knowledge conflicts, and in particular with defining their sources (e.g. [De Long, Seemann 2000; Yager 2000]) relate mostly to multi-agent systems composed of reactive agents, so the ones which are capable of drawing conclusions and adequately react to stimuli from the environment however do not have the cognitive function and have limited learning skills. With respect to the agents of this kind, knowledge conflicts occur in situations of opposition or in-coherence of the knowledge held by the agent [Hernes, Nguyen 2007; Korczak et al. 2013; Lorkiewicz 2006; Mianowska, Nguyen 2011; Sobieska-Karpińska, Hernes 2013]. However, works concerning the sources of knowledge conflicts with respect to cognitive agent (e.g. [Hensinger et al. 2004; Nguyen, Katarzyniak 2006]) are limited to very general approaches, and they do not take into consideration modules of agent's architecture. This may result from the fact that the implementation of various architectures of cognitive agents is currently mainly at a prototype stage and few of them function in commercial solutions and thus the problem of occurrence of knowledge conflicts is not raised. The work [Khalil et al. 2013], for example, presents using intelligent technologies, such as Bayesian Network Case-Based Reasoning, Expert System, Fuzzy System, Genetic Algorithms and Ontology Based techniques for resolving different types of conflicts – both reactive and cognitive agents, however, they are not related to agents' architecture. The work [Dastani et al. 2005] presents cognitive agents resolving methods only on the development stage (design time, programming), the knowledge conflicts at the runtime are not taken into consideration.

However, more intensive development of cognitive agent is noticeable, which may lead to a situation in which the knowledge of these agents will be so extensive that the issue of defining the sources of knowledge conflicts as well as the methods of their solving will become very significant both from a theoretical point of view and from the point of view of persons dealing with designing cognitive agents and multi-agent systems made of them. An automatic solution to the knowledge conflict, as stated in the study [Hernes, Sobieska-Karpińska 2013], is a key element of the functioning of multi-agent systems.

Thus the purpose of this article is to analyze the sources of knowledge conflicts occurring in the architecture of cognitive agent running in DSS.

The research has been realized in the following stages:

1. Studying the architectures of cognitive agents. The literature studies, a study of documents and the case studies have been used in this stage.

2. Analyzing of the DSS by using such research methods like the literature studies, the observation of phenomena in the enterprises, the case studies of different practical application of DSS.

3. Studying the knowledge conflicts issues. The literature studies, a study of documents and the case studies have been used in this stage.

4. Analyzing the possibility of knowledge conflicts appearing in cognitive agents' architecture functioning in DSS by using the observation of phenomena and case studies of prototype of cognitive agent. Also computer simulation has been used – selected framework of cognitive agents has been installed and the functioning of customer relationship agent has been simulated.

Realization of these research stages allowed for recognition of the issues related to the subject of this article.

## **2. The modules of cognitive agent's architecture as a potential places of knowledge conflicts sources**

The most important features of all cognitive agents' architectures include the way of their memory organization and learning mechanisms. The memory is the repository of the knowledge about the world and oneself, the objectives and current actions. The role of memory is understood differently by various authors [Dastani, Van der Torre 2002; Hawkins, Blakeslee 2004; Hecht-Nielsen 2007; Hensinger et al. 2004; Hernes, Sobieska-Karpińska 2013]. The organization of the memory depends on the manner of knowledge representation. Learning is a process which transforms the remembered knowledge and the manner of its use. In the study [Duch 2010] considering the taxonomy of cognitive agent architectures with respect to two above mentioned features, three main groups of the architectures were distinguished:

1. Symbolic architectures which use declarative knowledge included in relations recorded at the symbolic level, focusing on the use of this knowledge to solve problems.

2. Emergent architectures using signal flows through the network of numerous, mutually interacting elements, in which emergent conditions occur, possible to be interpreted in a symbolic way.

3. Hybrid architectures which are the combinations of the symbolic and emergent approach, combined in various ways.

It was decided to analyze in this article (due to its volume), with respect to the sources of knowledge conflicts, the architectures of the LIDA cognitive agent, proposed by S. Franklin [Franklin, Paterson 2006]. This is a hybrid architecture of

emergent-symbolic nature, owing to which the processing of both structured (numerical and symbolic) knowledge and unstructured (recorded in the natural language) is possible. In addition, the Cognitive Computing Research Group established by S. Franklin, elaborated in 2011 the framework (in Java language) significantly facilitating the implementation of the cognitive agent. It should also be emphasized that the whole framework code is open, i.e. the developer has access to the definitions of all methods, as opposed to, for instance, Cougaar architecture framework software, in which the agent's software code constitutes the so-called "blackbox". The LIDA cognitive agent's architecture consists of the following modules [*Cognitive Computing...* 2014; Franklin, Paterson 2006]:

- sensory memory,
- perceptual memory,
- workspace,
- episodic memory,
- declarative memory,
- attentional codelets,
- global workspace,
- action selection,
- sensory-motor memory.

In the LIDA architecture it was adopted that the majority of basic operations are performed by the so-called codelets, namely specialized, mobile programs processing information in the model of global workspace. The functioning of the cognitive agent is performed within the framework of the cognitive cycle and it is divided into three phases: the understanding phase, the consciousness phase and the selection of actions and learning phase. At the beginning of the understanding phase the stimuli received from the environment activate the codelets of the low level features in the sensory memory [Franklin, Patterson 2006]. The outlets of these codelets activate the perceptual memory, where high level feature codelets supply more abstract things such as objects, categories, actions or events. The perception results are transferred to workspace and on the basis of episodic and declarative memory local links are created and then, with the use of the occurrences of perceptual memory, a current situational model is generated; in other words the agent understands what phenomena are occurring in the environment of the organization. The consciousness phase starts with forming of the coalition of the most significant elements of the situational model, which then compete for attention so the place in the workspace, by using attentional codelets. The contents of the workspace module are then transferred to the global workspace (the so-called "broadcasting" takes place), simultaneously initializing the phase of action selection. At this phase possible action schemes are taken from procedural memory and sent to the action selection module, where they compete for the selection in a given cycle. The selected actions activate sensory-motor memory for the purpose of creating an appropriate algorithm of their

performance, which is the final stage of the cognitive cycle [Bytniewski, Hernes 2013]. The cognitive cycle is repeated with the frequency of 5–10 times per second.

Parallely with the previous actions the agent's learning is performed, which is divided into perceptual learning concerning the recognition of new objects, categories, relations; episodic learning which means remembering specific events: what, where, when, occurring in the working memory and thus available in the awareness; procedural learning, namely learning new actions and action sequences needed for solving the problems set; conscious learning relates to learning new, conscious behaviors or strengthening the existing conscious behaviors, which occurs when a given element of the situational model is often in the workspace. The agent's learning may be performed as learning with or without a teacher.

It is worth emphasizing that each cognitive agent supporting decision-making must have the ability of grounding the symbols, namely assign relevant real world objects to specific symbols of the natural language. This is necessary to correctly process unstructured knowledge saved mainly by means of the natural language and thus, for instance, the clients' opinions on products. The knowledge of this type is currently becoming more and more significant for a company because it may have impact on its competitiveness level. For instance analyzing the clients' opinions on a given product, the sales volume of a given product in the future may be estimated (of course with a certain level of probability).

Taking into consideration: the complexity of the cognitive agent's architecture and functionality, and asynchronous nature of the cognitive cycle (5–10 cycles per second) having impact on the contents of particular architecture models, it may be concluded that they may constitute the reasons for the occurrence of knowledge conflicts. Potential places of these conflicts' sources may occur in the modules of the cognitive agent's architecture and be connected with:

- the domain of the value of objects stored in memory,
- the results of phenomena interpretation,
- events,
- rules,
- the perception of the current state of the environment (objects and links between them),
- the results of algorithm operation,
- the selection of the agent's actions.

Further in the article the example of cognitive agents running in DSS will be presented.

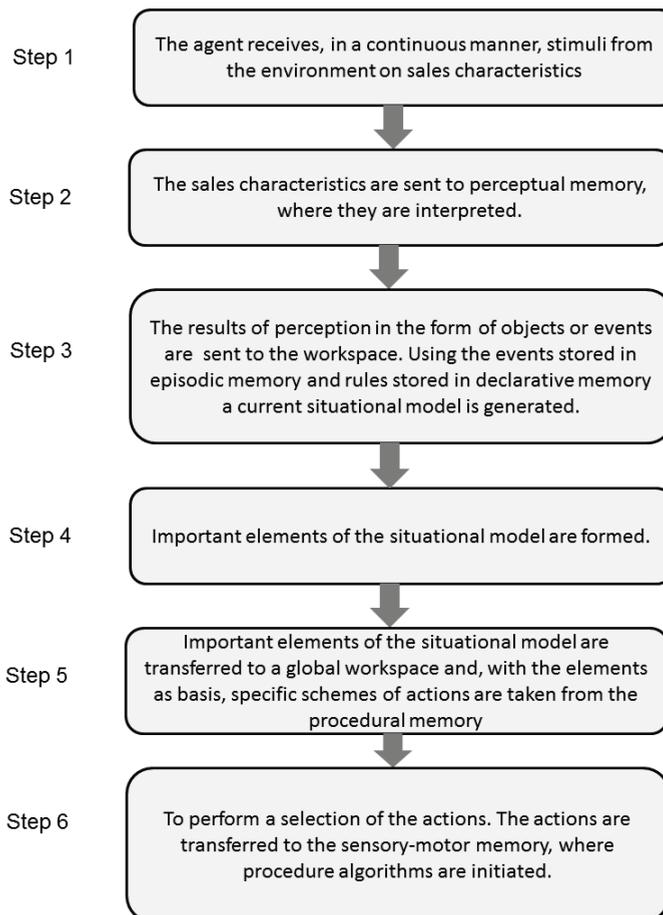
### **3. The customer relationship management agent**

The environment of the functioning of cognitive agents in DSS constitutes the company and its environment. The occurrence of knowledge conflicts is related to a situation when various values are assigned to the same objects, links between them,

features, phenomena events and actions occurring in the environment of the party to a conflict. Generating various decisions by agents, at the same time, may serve as an example [Sobieska-Karpińska, Hernes 2012, 2013].

For the needs of considerations made in the article, the sources of the conflicts of knowledge will be presented on the example of an agent, the objective of which is customer relation management. The functionality of this agent presents Figure 1.

In the first step the agent receives, in a continuous manner, stimuli from the environment on sales characteristics, such as sales dynamics indexes categorized into each customer, product opinion from customers (e.g. from the data base of the company's online shop), the characteristics of products offered by competitors, the characteristics of actions taken by competitors (e.g. from competitor monitoring



**Figure 1.** Functionality of the customer relationship management agent

Source: own elaboration.

agent). Sales characteristics are stored on an ongoing basis in the sensory memory of the agent.

Next, sales characteristics are sent to perceptual memory, where they are interpreted. For example, interpretation includes determination whether customers' opinions are positive or negative, determination of difference between characteristics of products offered by the analyzed company and offered by the competitors.

In the third step the results of perception in the form of objects or events are sent to the workspace. Then, using the events stored in episodic memory (for instance "last year witnessed a drop in sales", "two years before competitor introduced a product with better characteristics"), and rules stored in declarative memory (for instance "if user opinions are negative then sales will drop"), a current situational model is generated in the form of objects (e.g. sales characteristics), events (e.g. competitor's actions) and connections between them (e.g.: "competitor has offered a product with better characteristics and our company is witnessing a drop in sales").

At the step 4, important elements of the situational model are formed (the agent "rejects" unimportant elements of the situational model, e.g. "a drop in sales to customer X was noted, because he wound up their business activity" – the element is unimportant because no marketing action can be taken towards customer X).

Next, important elements of the situational model are transferred to a global workspace and, with the elements as a basis, specific schemes of actions are taken from the procedural memory – for instance "improve product characteristics" or "lower product price" or "introduce a new product that will meet customer expectations".

The last step is to perform a selection of the actions. For instance, the following actions will be selected: "lower product price", "introduce a new product that will meet customer expectations". The actions are transferred to the sensory-motor memory, where procedure algorithms are initiated – for example a set of steps to be taken in order to introduce a new product to the market.

The further part of article describes modules of agent's architecture from the point of view of the occurrence of conflicts of knowledge.

## **4. Sources of knowledge conflicts connected with DSS**

### **4.1. Sensory memory**

As sales characteristics are stored, on regular basis, in the agent's sensory memory, the contents of this memory may constitute the source of knowledge conflict. These conflicts are mainly connected with the domain of the value of objects stored in the memory. For instance, if it was adopted in the solution that the memory should include the users' opinions recorded in the text form, yet there occurs a situation in which the opinion contains graphic elements, their interpretation may be difficult or even impossible. As a consequence, the cognitive agent may incorrectly perceive the current state of the environment.

## 4.2. Perceptual memory

The knowledge conflicts occurring in the perceptive memory are thus connected with the results of its contents interpretation. For example, if an opinion contains only the product characteristics such as the color, dimensions, function, it is difficult to determine the polarity of the opinion (state whether the opinion is positive or negative).

## 4.3. Workspace, episodic memory and declarative memory

The perception results in the form of objects or events are sent to the workspace in which knowledge conflicts relate to the perception of the current state of the environment and are connected with the creation of local links with the use of events stored in the episodic memory and the rules stored in the declarative memory. Knowledge conflicts connected with the contents of episodic memory mainly relate to contradictory events which occurred as a result of the earlier event. For example, the earlier event recorded in the episodic memory is: “two years before the competition launched two products (which are also manufactured by the company in question) with better characteristics (product 1 and product 2)” and later events recorded in the episodic memory include: “in the previous year the sales of product 1 decreased” and “in the previous year the sales of product 2 increased”. The knowledge conflicts occurring in the declarative memory are connected with the occurrence of the contradiction of rules (for instance “if the users' opinions are negative, the decrease in sales will take place”, and “if users' opinions are negative, the sales will remain at the same level”).

Knowledge conflicts occurring in the workspace take place as a result of conflicts occurring in the episodic and declarative memory – the current situational model may contain incorrect objects or incorrect links between them.

## 4.4. Attentional codelets

In the attentional codelets module, there are significant elements of the situational model (the agent “rejects” insignificant elements of the situational model such as for instance “the drop of sales of products to the client X occurred because this client liquidated business” – this element is insignificant as no marketing actions can be taken with respect to client X any more). The conflict of knowledge in this module relates to the results of algorithm actions determining which elements of the current situational model are insignificant.

#### **4.5. Procedural memory**

The procedural memory, in turn, contains specific action schemes – for instance “improving the product characteristics”, “lowering the product price”, “launching the new product meeting the clients’ expectations on the market”. The conflict of knowledge relates to algorithms implemented as an action scheme, for instance determining what measures should be taken to launch a new product on the market.

#### **4.6. Action selection module**

The knowledge conflict in the action selection module relates to decisions which should be taken, for instance whether the action: “lowering the product price” or “launching a new product meeting the clients’ expectations” should be chosen.

#### **4.7. Global workspace and sensory-motor memory**

In the cognitive agent’s architecture there are also modules in which the sources of knowledge conflicts do not occur. They include: the global workspace (sources of knowledge conflicts do not occur in this module because there are significant elements of the situational model transferred from the module of current awareness for the purpose of initiating the phase of action selection) and sensory-motor memory (the sources of knowledge conflicts do not occur in this memory because it is a working module).

#### **4.8. Discussion**

It should be noticed that the occurrence of the conflict results in restrictions in the agent’s learning process. For instance, implementing perceptual learning, the agent may learn the interpretation of unknown economic indexes (for instance looking for their interpretation on the Internet – learning without a teacher or using human assistance – learning with a teacher). If, however, the index interpretations found are contradictory, the process of perceptive learning is disturbed.

And implementing procedural learning (learning without a teacher may be applied here as well the agent may use the actions defined in its own perceptive memory and assigned so far to other elements of the situational model), with a critic (for example the agent may assign particular actions implemented in connection with the decrease in the sales dynamics and a person defines whether the actions are correct) or with a teacher (the agent may for instance learn what actions should be taken in a situation when sales is dropping in a company and the competition is launching a new product). If the action algorithms are different (a knowledge conflict occurs), the learning process will be disturbed as well.

Knowledge conflicts occurring in the episodic memory have, in turn, a negative impact on episodic learning (performed without a teacher) consisting in remembering all events occurring in the environment.

Conscious learning (performed without a teacher), on the other hand, consisting in determining which elements of a situational model are significant, may be limited by knowledge conflicts occurring both in the workspace and in the attentional codelets module.

It should be also emphasized that the sources of knowledge conflicts may occur in other symbolic, emergent and hybrid architectures of cognitive agents. As similarly as LIDA architecture, their structure consists of many modules.

## 5. Conclusions

The use of cognitive agent in DSS allows for the implementation of actions performed in a company by a human being so far, starting with the operation of work stations, through the diagnosis of the current economic situation to automatic decision-taking – at the operational, tactical and strategic level. This is connected with the agents' skills in the scope of correct interpretation and associating of facts, discovering links between the objects and phenomena of the real world, learning and having experience.

For cognitive agent to be able to effectively perform their tasks, they should be created upon conducting the analysis of particular modules, with respect to knowledge conflicts. Thus the identification of the sources of knowledge conflicts, presented in the article, and their consideration at designing the decision-making process support systems will allow for automatic detection of conflicts of this kind and, as a consequence, their solving. These actions are extremely significant because, as has already been emphasized, they have a positive influence on the effectiveness of processes performed by an agent, and, in turn, the effectiveness of decisions taking place in a company.

This results in the need to perform further research works connected with, among others, the elaboration of the formal model of conflict solving and the creation of the prototype of cognitive DSS.

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## **ŹRÓDŁA KONFLIKTÓW WIEDZY W ARCHITEKTURZE AGENTA KOGNITYWNEGO W SWD**

**Streszczenie:** W artykule przedstawiono problematykę identyfikacji źródeł konfliktów wiedzy w architekturze kognitywnych programów agentowych. Agenty te funkcjonują w systemach wspomagania decyzji. W pierwszej części artykułu scharakteryzowano rodzaje architektur agentów kognitywnych oraz przedstawiono przykład takiej architektury. Następnie zaprezentowano przykład funkcjonowania agenta kognitywnego wspomagającego zarządzanie relacjami z klientami oraz określono przyczyny występowania konfliktów wiedzy. Końcowa część artykułu zawiera analizę źródeł konfliktów wiedzy i ich przykłady związane z funkcjonowaniem systemów wspomagania decyzji.

**Słowa kluczowe:** konflikty wiedzy, kognitywne programy agentowe, systemy wspomagania decyzji.