Integration of knowledge management systems and business processes using multi-agent systems

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Integration of knowledge management systems and business processes using multi-agent systems

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Abstract: Applications of agents in supporting the organisation's operations largely refer to issues connected with business processes and management of the organisation knowledge. Multi-agent systems are perceived as an element that performs and automates business processes of an organisation and substitutes its IT systems and users. Agent solutions are also perceived as tools designed to automate or support the user in different stages of the life cycle of the knowledge management system. This paper presents the concept of an original solution ensuring integration of knowledge management systems and business process. The first part of the paper presents current research in the area of integration of software agents within business processes and the processes of knowledge processing. The second part presents the architecture of a software solution designed to support the modelling of business processes and improve these processes. The third part shows an example of using this architecture.

Keywords: knowledge management; user-agent collaboration; software agents; business process modelling.

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1 Introduction

Current research on agent technologies supporting business processes and their use in the context of supporting the building of knowledge management systems (KMSs) shows that agent solutions can support both these approaches. In order to be successful in an

organisation, it is necessary to consider the organisational, technical and social aspects in the construction of such solutions (Meier, 2007). In particular, the goals of an organisation, as defined by the processes it performs, should have an influence on developed systems of knowledge management, which should ensure the knowledge necessary to perform these processes, affecting the goals that are implemented and the results (Hog and Aker, 2012). As a result, KMS should directly cooperate with systems designed to support the realisation of business processes (Gourova and Toteva, 2014). Gourova and Toteva indicated that KMS should support the identification of knowledge needs, gather and store such knowledge and support its sharing within business processes. Additionally, they should support creation of knowledge during performance of processes.

It can be assumed that knowledge-based organisations use intellectual capital to manufacture products and provide services. They also consciously manage intellectual capital and are capable of learning. In other words, knowledge-based organisations are those that adapt their offer and way of acting to knowledge gained by reflecting on how they previously acted and that consciously manage knowledge resources they possess.

The use of software agents in organisations tackles twofold benefits: On the one hand, it is necessary to look for tools that will support the designing of business processes taking place in organisations. On the other hand, will support the performance of such processes by providing relevant knowledge. In particular, such solutions should support specific stages of the life cycle of the KMS (Żytniewski, 2013; Di Nitto et al., 2002). Of special importance in the process of building KMS is the aspect of knowledge sharing among users and the context of its use. Such knowledge should be contextual, dependent on the process in which it is used and specific tasks it supports. For that reason, it is necessary to look at KMS from the perspective of virtual organisation in which users share possessed knowledge in a virtual community (Fahad et al., 2014). In such systems, users should share not only subject and process knowledge, but also meta knowledge on knowledge resources. Thus, it is necessary to build solutions that are at the interface of process-oriented systems and KMSs, which will support their integration and knowledge sharing among participants.

The aim of this paper is to present the concept of an original solution that ensures integration of KMS with business processes handling and is supported by agent systems. The first part of the paper presents current research in the area of integration of software agents within the processes of knowledge processing. In particular, it indicates the requirements for a solution designed to support business processes and manage knowledge about such processes. The second part presents the architecture of a software solution designed to support the modelling of business processes and improve them by ensuring their participants access to organisational knowledge. The third part shows an example of using this architecture.

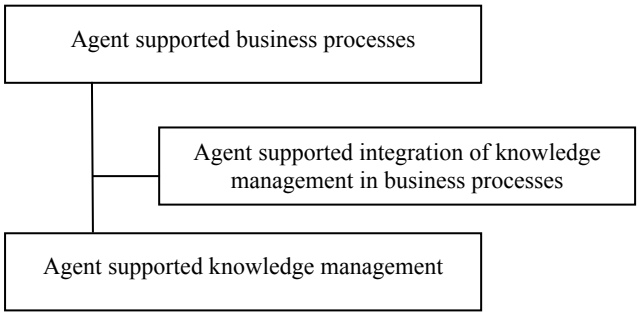
2 State of arts

Modern organisations are looking for software systems that are able to improve their business processes. This kind of software should support users' interaction during business process realisation and propagation of the knowledge among them. One of the solutions that can help this process are multi-agent systems, which typically are

considered as part of a business process or KMS. This paper will address the issue of creating agent-oriented solutions that enable integration of KMS in the area of business processes performed by an organisation.

Figure 1 shows that the subject of using software agents within an organisation requires considering three aspects. The use of agents as an element supporting business processes, as an element supporting knowledge management and the use of agents to support the integration of both these approaches, which is the subject of this paper.

Figure 1 Approaches to using agents in business processes supported by KMSs



2.1 Agent supported business process

Modelling of business processes is focused on achieving a specific goal by performing defined tasks. Users' goal and tasks constitute a key element being one of the components defining the business process (De la Vara Gonzalez and Diaz, 2007; Smith and Fingar, 2003). When defining business processes in the context of an organisation, the goal and tasks are viewed within the scope of actions performed by the participants of the process. A goal that is achieved through the process is complex by nature and requires development of a range of activities that have to be defined. These activities, according to the theory of modelling business processes, should be indivisible and clear. On Figure 1 one has indicated that agent societies may support the realisation of both business processes and knowledge management processes, which should be considered separately.

In the case of an agent-supported process, the goals can be treated as the goal of a multi-agent system (Soffer, 2005). In this case, we can say that the task of an agent is to substitute the activities of the user. However, in the case of atomic tasks, goals of an agent can be twofold. They can consist in performing a specific task (substituting a human being) or supporting the user's actions.

The first case (performing a specific task) refers to the performance of business processes by software agents. Research in this area focuses mainly on decomposition of business processes and their performance by agents (Endert et al., 2007; Onggo and Karpat, 2008) and concentrates on modelling multi-agent systems as the performer of the system's tasks.

In the second approach (supporting users' actions), the use of software agents consists in providing the user with appropriate knowledge required in the context of the goal, process or task in which this person participates (Hess et al., 2008). In both cases, both agents and users have to possess knowledge appropriate for the context of their activity

that allows them to perform the tasks assigned to them. This knowledge can come from the systems of an organisation knowledge management.

2.2 Agent supported knowledge management

In case of application of software agents in the process of support of KMS, the tasks of the software agents are different. They refer to specific stages of the life cycle of the KMS. In the context of direct support for business processes, the task of such solutions is to ensure appropriate knowledge to the user or agent acting on specific person's behalf in a specific business process. Since the research presented in this paper refers to integration of agent-supported KMS in business processes, it is necessary to analyse these solution more closely. In a work by (Dignum, 2006) one presented a threefold division of agent solutions in the area of an organisation knowledge management. The researcher indicated three types of agent systems which may be applied for the KMSs support:

- interface agent, conversational agent
- homogeneous multi-agent system (cooperating software agents)
- heterogeneous multi-agent system.

The application of the first and second type of agents can be examined here in the context of using interface agents and chatterbots as an element supporting the tasks performed by the user and providing him/her with appropriate knowledge. The use of such solutions supporting knowledge management in an organisation largely results from the human nature and problems with human memory which cause the knowledge on certain processes to be lost and forgotten if such processes are not regularly repeated (Lindsey et al., 2014).

It can be noted that typical KMS make users' knowledge available in the form of documents and links to specific knowledge resources. Usually researchers (Kay, 2007) points out here that the use of various methods of information presentation can support and improve cognitive processes. However, quite often, a participant of a business process requires a more complex answer to the problem the user encountered. For instance, how the process in which the user participates looks like, how certain documents should be prepared or what certain terms mean. In this case, it is necessary to use solutions that support a direct dialogue where specific questions of the user find proper answers (Shawar and Atwell, 2007).

In the case of teaching processes, in particular intelligent tutoring systems or learning management system (Schamp-Bjerede, 2010), the use of chatterbots brings measurable benefits, as such solutions support teaching processes through possessed knowledge, substituting in certain situations an expert in a specific area. In this case, they can be perceived as a teacher (Kerly, 2006) which is designed to achieve the goal of knowledge building (Schamp-Bjerede, 2010). In this situation, a chatterbot allows the user to obtain the answer to the encountered problem. In particular, research in this area shows that in the case of teaching processes such solutions are an important element supporting educational processes by increasing the participants' involvement in learning (Benotti, 2014).

The research into the use of chatterbots presented herein shows that they can be used in teaching processes, but from the perspective of the operation of an organisation they

are more difficult to use. This result from the changeable nature of business processes, which are subject to frequent changes. In the case of Intelligent Tutoring Systems, the schedule and the objectives of a teaching process are relatively stable.

Another problem is changeability of knowledge. In the case of an organisation and its environment, there are continuous changes in knowledge that is used, which requires constant updating and assessment of knowledge. In the case of learning process, these changes are cyclical. Thus, the use of solutions in the form of chatterbots within an organisation KMS is more difficult and requires creation of solutions that will allow them to be directly integrated in business processes and will ensure their constant evaluation in terms of usefulness. Referring to the issues discussed in Section 2.1, it can be said that the use of such solutions is focused on supporting actions of a human being. From the perspective of knowledge management, they should be perceived as an element supporting knowledge dissemination.

The use of multi-agent solutions in the third approach largely refers to using them to support selected actions within an organisation. In this approach, multi-agent systems are treated as an element that supports knowledge processing in KMS and as an element of the system architecture. Such solutions are implemented in an organisation, for instance, to support software management processes (Nor et al., 2010), support Call Centre systems (Popirlan, 2010; Das et al., 2002) where information systems are used in the process of data search using SQL language (Żytniewski and Kowal, 2013) or to support a consulting company. While such solutions support specific elements of the life cycle of the KMS, their problem orientation makes them narrowly specialised in the area of supporting a selected area of an organisation's operation and there is no question of their integration with other business processes and knowledge databases.

On the other hand, academic literature includes works addressing the aspect of knowledge processing. Monticolo et al. (2012) points out the necessity to perceive software agent societies as an element supporting knowledge integration in an organisation by showing a possible use of an agent system in the process of integration of IT systems in the context of using semantic methods of knowledge representation (Gandon et al., 2002). In this case, such a solution is focused on automation of the process of semantic knowledge processing based on data in relational databases.

2.3 Agent supported integration of knowledge management in business process

In the area of integration of KMS and business processes, one can indicate such solutions as presented by Jucovschi (2013). However, the problem of integration of common or Business Intelligence applications within KMS was earlier addressed by Rizwan et al. (2013). The concepts mentioned in Sections 2.1 and 2.2 shows a diversity of both the approaches in modelling the functionality of agent systems, resulting from the specificity of their application. In the context of agent solutions supporting business processes from the perspective of an organisation, as presented in Section 2.1, an employee or agent participating in a business process should possess appropriate information and knowledge that will allow him/it to properly perform the task in which he/it participates. Additionally, such knowledge should relate to the place and time of performing a business process. From the perspective of KMS, the task of software agents is to provide the participant with appropriate knowledge, which is required in the context of the process in which it participates and the task it performs. In this case, agent

supported solutions integrating KMS and business process management systems should have the following functions:

- extending currently used standards for describing business processes to include sources of knowledge that supports the performance of users' tasks (in the context of the process, place and time)
- enabling direct integration of organisational knowledge within any business processes taking place in an organisation within the scope of the process in which this knowledge should be used and the task that it supports
- automating processes of assessing the functioning of KMSs in terms of their usefulness in supporting business processes
- generating new organisational knowledge at the interface of business processes and knowledge management
- using semantic mechanisms for knowledge description for easier integration of possessed knowledge with internal organisational knowledge
- independent operation from used IT solutions and enabling integration of any KMSs and a process-oriented solution.

The software solution presented in the next chapter fulfils all the above-mentioned requirements.

3 System proposition

This section will present the functional scope and architecture of a solution being built. The system is built based on JAVA language and uses various libraries, including the JADE multi-agent platform, JENA mechanisms for ontology semantic processing, OWL language for knowledge representation and BPMN standard for business process modelling. The subsequent section will present an example of using the architecture for modelling a business process and defining knowledge resources used in it.

The aim of the developed solution is to support processes of describing knowledge resources of organisations as part of business processes taking place in them. The solution is agent oriented, as it is possible to define software agents and multi-agent systems as knowledge sources for a process. Multi-agent system is a component of the proposed software, which is used in the process of analysing gathered knowledge and its codification by means of semantic mechanisms. This section will present a fragment of the system functionality in the area of modelling the business processes in BPMN along with the adopted artefacts extending its features and the use of a mechanism for evaluating interface agents in performing the user's tasks.

3.1 System architecture

The research on cooperation of KMS, systems supporting business processes of organisations and agent technologies resulted in the development of a system architecture that consists of seven layers (Żytniewski, 2015) (Figure 2).

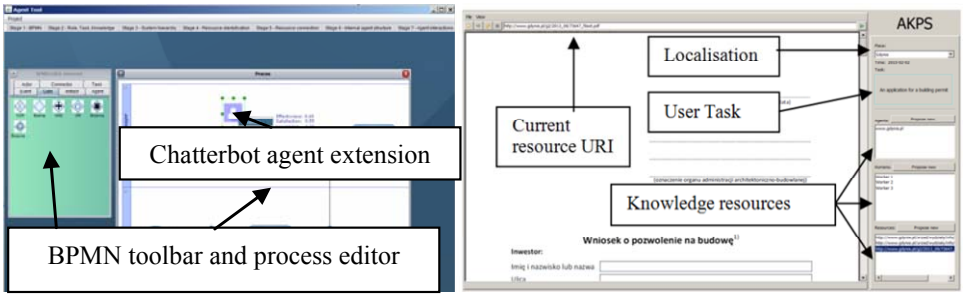
Figure 2 Layers of the agent system for supporting knowledge management in an organisation

	Layer 1. Users	The layer of personalisation and communication
	Layer 2. Business process	
The layer of management of knowledge portal	**Layer 3. Knowledge portal and chatterbots**	
	Layer 4. Agent evaluation tool	The layer of management of software agents society
The layer of knowledge sharing	**Layer 5. Multi-agent system**	
	Layer 6. Ontology	The layer of knowledge storing
	Layer 7. Database layer	

Layer 1 refers to the participant of a business process. It can be a company's employee, customer, department of an organisation or other software agent. It was assumed in the architecture that the main reason for such an entity's willingness to participate in processes of the organisation is acquisition of certain knowledge. This, however, does not result from willingness to learn, but from the necessity to perform specific tasks that have been assigned to it. In this case, the knowledge it has to possess is determined by the task in which it participates, and the system of knowledge management should provide it with specific tools to support the performance of this task, taking into account the context of the process in which it participates.

Layer 2 refers to business processes. A frequent problem encountered by users is to locate the knowledge required in the processes in which they participate, therefore this layer should support modelling of business processes. Based on an analysis of notations currently used for specification of business process, the author used BPMN extended by additional artefacts to allow to identify how agents, knowledge portals and other participants impact a process. An advantage of this approach is the fact that KMS are linked with an organisation's business processes. Figure 3 shows an example of business process modelled in BPMN in an IT system supporting business processes of an organisation and its representation in the tool developed.

Figure 3 The example of user interface (see online version for colours)



The architecture of a business process modelled in this way makes it easier to indicate which information should be made available to users while they perform actions.

In order to expand the features of BPMN model, one has offerred a set of artefacts which support the integration of the KMS with the business process. They include the

artefacts of: interface agent, multi-agent system, knowledge resources and consultant (Żytniewski, 2015). The use of such artefacts makes it possible to contextually connect the knowledge resources of an organisation within a specific process and task. This shortens the time it takes for the users to acquire new knowledge, because described knowledge resources become available to each participant of a business process that performs a specific task. The addition of a new knowledge resource by the user is recorded in the system and made available to users performing the same process and a specific task. This supports cooperation between users, as each of them becomes the creator and receiver of the system knowledge.

Figure 3 presents an interface of access to knowledge resources of a KMS in the context of the process and task.

This interface presents knowledge resources that can be used in the context of a business process and task performed by the user.

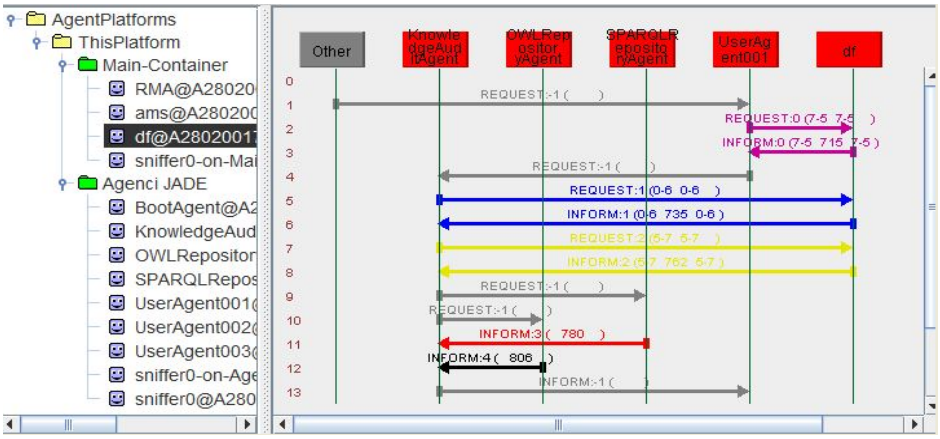
Layer 3 of the system is knowledge portal and interface agents. The task of this layer is to promote knowledge on processes taking place in an organisation and to use semantic mechanisms in the form of chatterbots. It has been assumed in the developed architecture that both these elements can constitute a part of the system for an organisation knowledge management or exist outside IT systems of the organisation. For that reason, the solution proposed should support the integration of them both. This layer can be treated as the interface of an organisation KMS indicated in Section 2.2.

The next solution is a tool for evaluating an agent's usefulness, which constitutes of *Layer 4* that refer to the developed architecture. This tool makes it possible to interactively define a template for evaluating the usability of an interface agent and define four parameters of the operation of an agent: effectiveness, performance, satisfaction and knowledge sharing (Kopka and Żytniewski, 2014). The use of this tool supports the process of selecting agents for specific tasks they are supposed to support and allows the operation of an agent to be evaluated.

As shown in Section 2.2, interface agents, in particular chatterbots, can be an element of dissemination of the organisational knowledge. However, their use in the context of knowledge sharing should be subject to evaluation, due to changeability of business processes and possible obsolescence of an agent's knowledge. The solution proposed enables the analysis of any chatterbot agent published in the internet. During evaluation of an agent, the user is regularly informed about, among other things, which task the agent should support, how long conversation lasts and how many questions the user has already asked. Then, the user is asked to complete a satisfaction survey concerning the conversation. Based on that, the system calculates the agent's usability indicators for a specific task in which it was used (Kopka and Żytniewski, 2014). This is important, as it may turn out that despite its broad knowledge the agent does not support appropriately the specific tasks. In such a case, it would be necessary to update its knowledge database. Moreover, its knowledge may become obsolete. The mechanism defined in this way makes it possible to identify such situations.

Layer 5 of the tool developed is the layer of a multi-agent system. In the architecture designed, it is perceived as a tool for evaluating knowledge acquired in the process of using the method indicated above and as a tool to build a multi-agent system, substituting the user in accordance with the developed methodology focused on business processes. For implementation of this layer, JADE platform was chosen and a set of agents supporting the process of knowledge evaluation and codification was prepared (Figure 4).

Figure 4 Elements of a multi-agent platform (see online version for colours)



The architecture developed includes couple of software agents' roles (Figure 5) (Żytniewski, 2015).

The first role of a <<JADE Platform Agent>> (the << >> symbols indicate the designation of the agent's role) indicates that the proposed solution was developed using the JADE platform. Relation ending with lozenge indicates a management relationship, because the agents defined on the platform are responsible for controlling the proposed agent society. The role of a <<Getaway Agent>> applies to an agent starting the proposed system. Its task is to create new agents that are part of the society. The role of <<Respository Agent>> refers to agents that store specific resources in the form of defined knowledge or program codes used by the agent society. The last role is <<Worker Agent>>, an agent working in the context of a user. On the basis of such defined roles the following agents were proposed:

- BootAgent <<Gateway Agent>> – agent responsible for activating the multi-agent system. Its task is to create agents and activate agent instances of the individual users of the system.
- KnowledgeAuditAgent<<Worker Agent>> – agent responsible for the process of analysing the knowledge of the system. It generates usability indicators for the different knowledge resources.
- OWLRepositoryAgent <<Repository Agent>> – agent responsible for the process of maintaining the knowledge database of the platform.
- SPARQLRepositoryAgent <<Repository Agent>> – agent handling database of queries concerning the knowledge database of the platform.
- UserAgentXXX <<Worker Agent>> – instance of a user agent generated during the operation of the platform.

Figure 6 shows the corresponding relationships between agents' roles and classes.

Layer 6 of the architecture being developed is the ontology layer. It is used as an element of semantic specification of the terms used by agents and enables description of

knowledge resources in an organisation. The elements of the ontology are presented in Figure 7.

Figure 5 Agent roles in proposed system (see online version for colours)

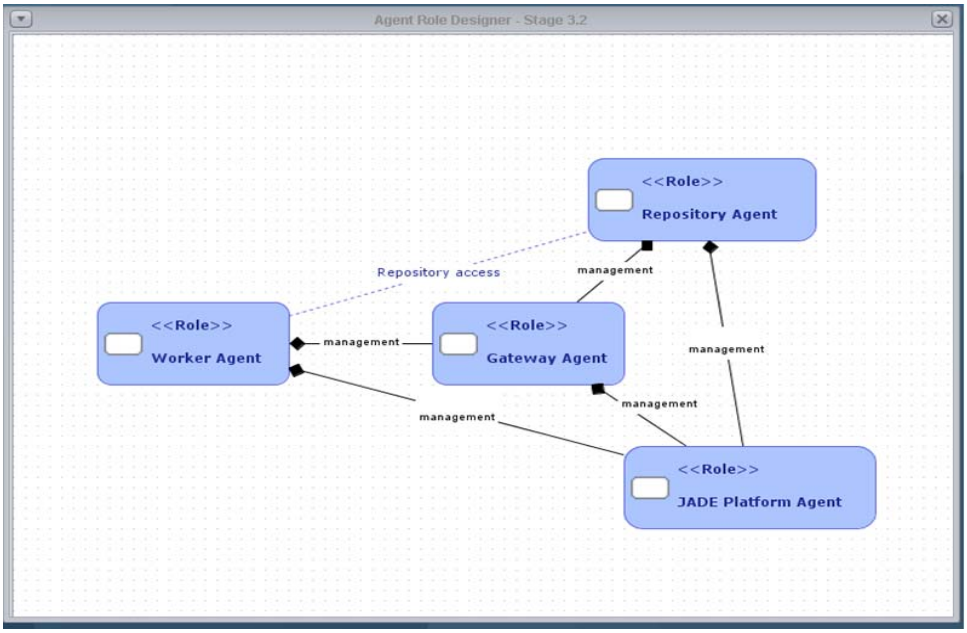


Figure 6 Agent role-class relation (see online version for colours)

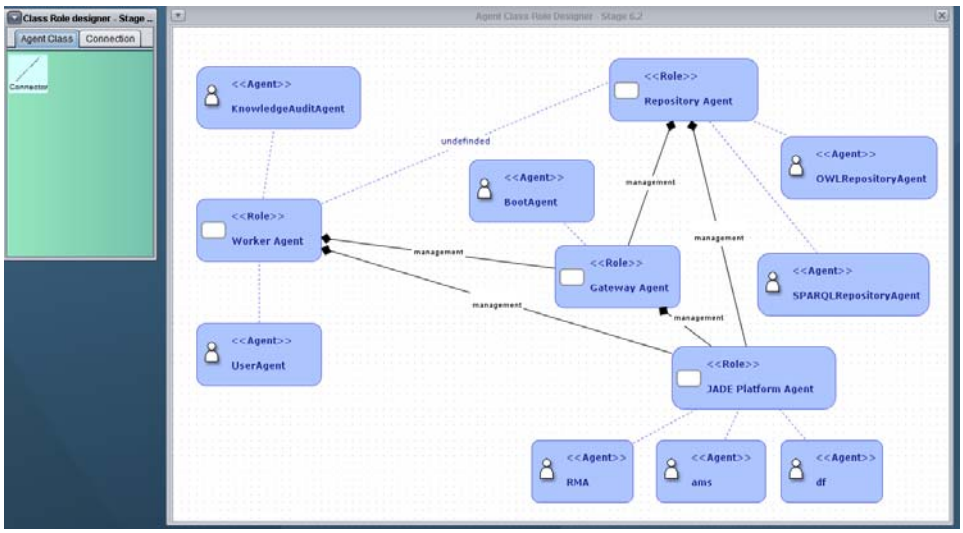
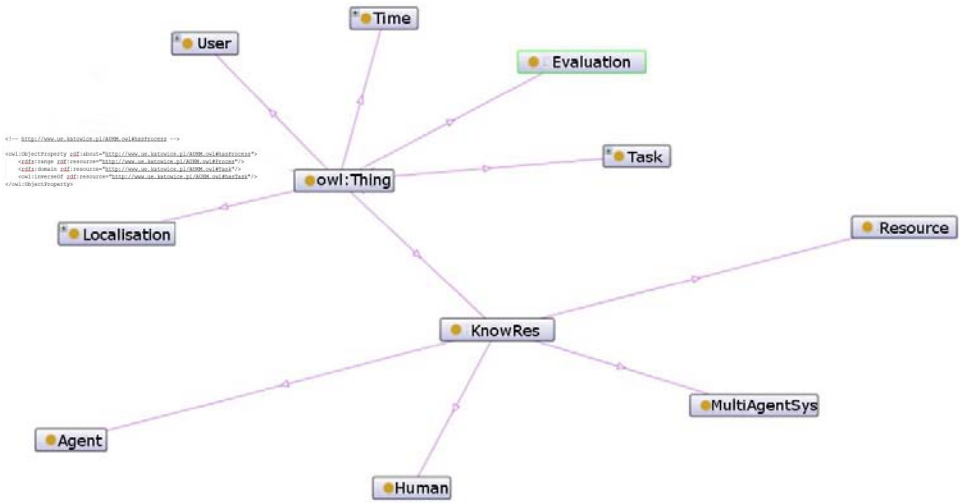


Figure 7 Part of the OWL ontology prepared (main concepts) (see online version for colours)



This layer enables semantic coding of the knowledge of the system proposed and its processing by means of SPARQL queries. The use of this layer contributes to propagation of the possessed organisational knowledge and is consistent with the concept of Web 3.0. It also contributes to the propagation of knowledge about an organisation and processes taking place in it, and use of this knowledge by a multi-agent system in the process of analysing organisational knowledge.

In the proposed ontology, it was indicated that the main terms represented in the system are the following:

- localisation – defining the place of realisation of the business process
- process – business process developed in accordance with the notation proposed in this article
- user – person looking for knowledge on the realisation of business process
- time – defining the criterion of time when the process is realised
- evaluation – indicating the results of agent's usefulness evaluation
- task – task realised as an element of business process to which an element of knowledge defined in the model can be assigned
- knowledge resource – element of knowledge concerning the agent, multi-agent system, user or knowledge resources.

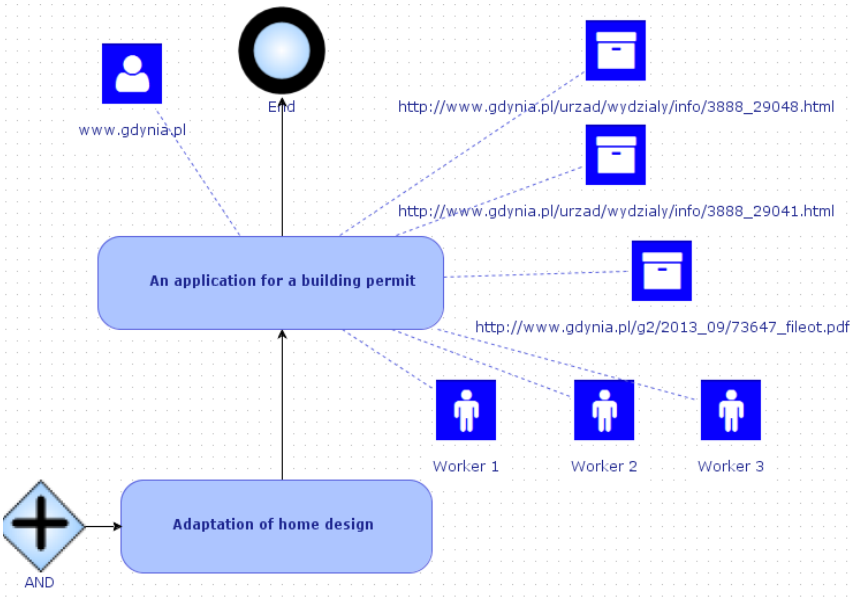
The last layer 7 concerns the aspect of storage of data generated by the proposed solution. In the process of an elaboration of the system, one has used various technical solutions, that include the network services or databases service mechanisms.

3.2 Example of the proposed application

The system architecture developed is designed to support business processes; therefore, its central module is the module of designing business processes in BPMN notation. Such a process may come from other IT systems existing in an organisation or may be prepared based on an established model. The example shows a process of obtaining a planning permission. When applying for a planning permission in Poland, it is necessary to collect a range of documents.

The business process which part is presented on Figure 8 was elaborated in accordance with the BPMN notation with use of a prototype of a tool for modelling the business processed. The elaborated tool supports the business processes modelling based on the defined components and allows to expand it. In the proposed process one has indicated 11 tasks which have to be performed by the user who wants to obtain a building permit. The last stage will be expanded with additional knowledge resources which will be indicated by the business process users. While the process of collecting documents itself is widely known, such documents and their content may vary across different places in Poland where they are prepared. The places of their storage also will vary. Therefore, the process illustrated in Figure 8, though correct for a specific person, is general and it can be used for a reference only. The application of the proposed solution makes it possible to extend this process by the context of its use in a specific place and time and with chosen knowledge resources.

Figure 8 Extended process of obtaining a planning permission (see online version for colours)



As a result, the person performing such a process may become equipped with additional knowledge on its course and the source of this knowledge. This person also has access to relevant documents that have to be completed. In the example above, it has been diagnosed that in the city of Gdynia there is an interface agent (published on the website

http://www.gdynia.pl/), whose task is to support users' actions. By means of the interface created, it is possible to evaluate it in the context of place, time and process. As a result, the user getting access to the process may decide based on the agent's usefulness indicators whether to use it or not.

Based on the interface of evaluating an agent's knowledge, the multi-agent system prepares evaluation of its usefulness in this task, which is included as an element of description of a business process. The algorithm of the process of analysing the agent's usefulness is presented in Figure 9.

Figure 9 The algorithm of the process of analysing the agent's usability based on OWL concepts (performance parameter)

```
BEGIN
// connect OWL instances
for each LOCALISATION(l)
  for each PROCESS(x)
    for each TASK(y)
      for each AGENT(a)
       if hasTask(x, y) AND hasAgent(y, a) AND hasLocalisation(y, l)
          GET x and ADD to set A
       end if
      end for
    end for
  end for
end for
// set agent performance in connected process, task and localisation
for each A(x)
  for each EVALUATION(e)
    if hasEvaluation(x, e)
      i := i + 1;
      p := p + e.performance;
      x.performance := p/i
    end if
  end for
end for
END
```

Based on that, the system enables calculation of the agent's usability in the context of the task that it supports, place and time of its performance (Figure 10). The presented usefulness indicators may concern multi-agents assigned to the same process. It results in the fact that it is possible to indicate which agent is more useful in the process of support of a given task. In case when the indicators of a given agent vary from the assumed level, it is possible to exclude it from the solutions supporting a given task. The user may also use other knowledge resources that have been assigned to a given process.

As a result, for a given business process, it is possible to develop extended BPMN process model connected to knowledge resources and a map of agents' effectiveness in supporting the different business tasks.

The proposed approach enables us to include the users in the process of knowledge management on the processes realised by them. The users may define a business process, assign resources to it in the form of documents, websites and program agents. Such knowledge extending beyond the description of the process realisation may be shared and updated by persons analysing the given business process. Currently the process

formation, adding new documents and websites and indicating the agents supporting these processes may be conducted by the users. In a case of the evaluation process, the activity itself and the analysis of its results require the work of analyst, as only the processed data can be used by the multi-agent system for the purpose of calculation the defined values in accordance with the proposed algorithm.

Figure 10 Preview of agent usability (see online version for colours)

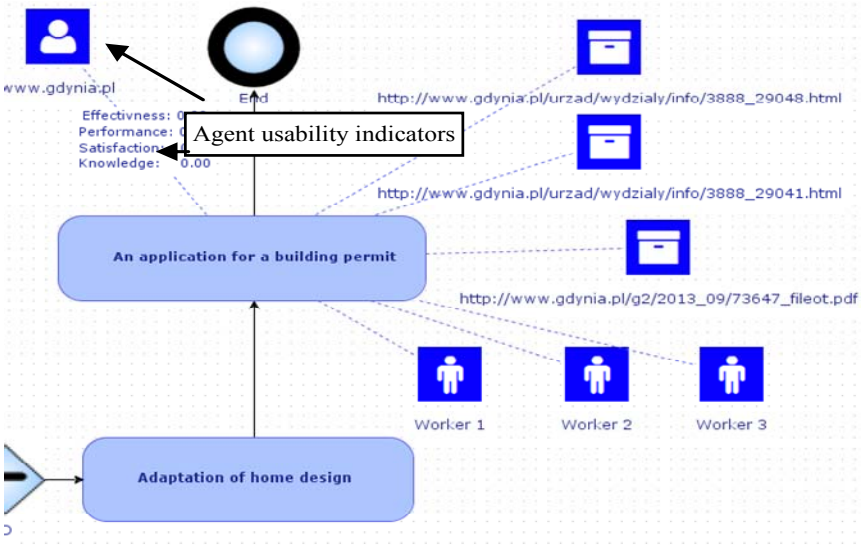
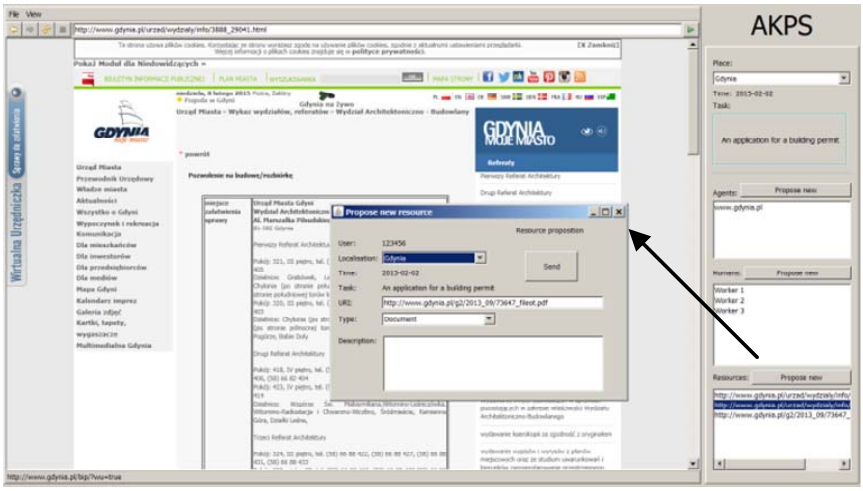


Figure 11 presents the process of assigning new knowledge resources.

Figure 11 The process of assigning knowledge to a process by the user (see online version for colours)



4 Conclusions

This paper addresses the issue of modelling the agent-supported systems designed to integrate KMS within business processes performed by an organisation and its environment. For that purpose, this paper propose the concept and architecture of the KMS supporting the business processes of an organisation. The proposed solution enables the integration of various agent solutions within modelled business processes, regardless of the level of agent socialisation indicated by Dignum (2006).

The approach proposed herein offers the following advantages:

- It directly relates to currently used standards for modelling business processes.
- It proposes extension of BPMN to include additional artefacts connected with description of knowledge resources.
- The solution developed can be used as an element of a process-oriented IT system without interference into its architecture.
- It allows knowledge resources to be assigned to processes, tasks, place and time of their performance. This enables better adjustment of knowledge resources to the context of knowledge use.
- It allows knowledge resources to be evaluated. The current version of the solution enables evaluation of an agent interface, usability and conversation with the employee.
- It automates the process of knowledge evaluation using a prepared multi-agent system.
- It enables integration of represented knowledge resources through the semantic layer (OWL ontology) with other solutions.
- It enables for the sharing of knowledge between the business process' users.
- It enables the definition of tasks to be supported by the KMS, which has influence on the knowledge resources offered to the process' participants.
- It involves within the process of defining the knowledge resources not only with the system creator but also with the users to which ensure their greater engagement.
- It integrates the program agents within the business processes offered in the organisation, which makes it easier to define the level of support of particular tasks within the business processes.

Current research on this architecture focuses on the use of multi-agent systems as an element supporting business processes. The original methodology of designing such a solution and elements of the tool supporting the modelling of such solutions will be the subject of the author's further research.

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