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

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ABSTRACT

Applications of agents in supporting an organisation's operations addressed in academic literature largely refer to issues connected with business processes and management of an organisation knowledge, which are considered separately. In the first case, multi-agent systems are perceived as an element that performs and automates business processes of an organisation and substitutes its IT systems and users. In the second case, agent solutions are perceived as tools designed to automate or support the user in the different stages of the life cycle of the knowledge management system. The research discussed in this paper addresses the aspect of integrating both these approaches and refers to the point where both these classes of systems meet. The aim of this paper is to present the concept of an original solution ensuring integration of knowledge management systems and business process handling, which is supported by agent systems. 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 by ensuring the process participants access to organisational knowledge. The third part shows an example of using this architecture.

Categories and Subject Descriptors

I.3.6 Methodology and Techniques

H.5.3 Group and Organization Interfaces

General Terms

Human Factors, Verification, Experimentation, Design

Keywords

knowledge management, user-agent collaboration, software agents, business process modelling

1. INTRODUCTION

Current research into agent technologies supporting business processes and their use in the context of supporting the building of knowledge management systems shows that agent solutions can support both these approaches. To be successful in an organisation, such systems should constitute synergy of organisational, technological and human-focused initiatives and tools [17]. 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 results [11]. As a result, knowledge management systems should directly cooperate with systems designed to support the realization of business processes [9]. This relationship can be seen in figure 1.

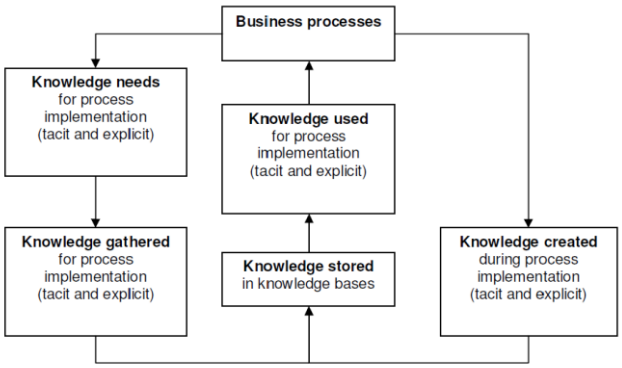

Figure 1. Relationship between knowledge management and business processes

Sources: [9]

As figure 1 shows, knowledge management systems 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.

Such a definition of tasks results from the fact that knowledge-based organisations use intellectual capital to manufacture products and provide services, 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.

In order to use software agents in organisations, it is necessary to look for tools that will support the designing of business processes taking place in organisations on the one hand, and will support the performance of such processes by providing relevant knowledge on the other hand. In particular, such solutions should support specific stages of the life cycle of the knowledge management system [27],[5].

Of special importance in the process of building knowledge management systems 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 knowledge management systems from the perspective of Virtual Community (VO), in which users share possessed knowledge in a virtual community [6]. 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 knowledge management systems, 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 knowledge management systems 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 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 these processes by ensuring their participants access to organisational knowledge. The third part shows an example of using this architecture.

2. STATE OF ARTS

This paper will address the issue of creating agent-oriented solutions that enable integration of knowledge management systems in the area of business processes performed by an organisation.

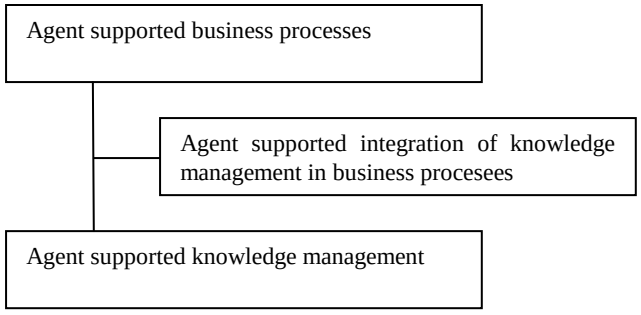

Figure 2. Approaches to using agents in business processes supported by knowledge management systems

Figure 2 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.

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 defining a business process [3] and are often mentioned in its definition [25]. When defining business processes in the context of an organisation, a goal and tasks are viewed within the scope of actions performed by the participants of a process. A goal that is achieved through a process is by nature complex 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.

In the case of an agent-supported process, the goals of a process can be treated as the goal of a multi-agent system [26]. In this case, we can say that the task of an agent is to substitute 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 his/her actions.

The first case 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 [7],[20] and concentrates on modelling multi-agent systems as the performer of the system's tasks.

In the second approach, 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 he/she participates [10]. 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

Tasks of software agents as part of knowledge management systems vary. They refer to specific stages of the life cycle of the knowledge management system. 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 his/her behalf in a specific business process. Since the research presented in this paper refers to integration of agent-supported knowledge management systems in business processes, it is necessary to analyse these solution more closely. In his work V. Dignum [4] presented a threefold division of agent solutions in the area of an organisation knowledge management (table 1).

Table 1. Threefold division of agent solutions in the area of an organisation knowledge management

Interface agent, conversational agent	An entity operating in isolation from other software agents, lack of mechanisms for communication with agents, orientation towards communication with a human being, possession of a local knowledge database and an artificial intelligence mechanism. Possible connection with an organisation's IT systems through

	defined interfaces.
Homogeneous multi-agent system (cooperating software agents)	Agents have a mechanism for communication with other agents (usually an interface), it uses certain communication standards and queries generation languages, uses other agents' knowledge database, e.g. interface, is able to adapt other agents' knowledge for its own needs. It operates locally in terms of cooperation with the user. It uses agents of one type. The tasks they perform and their abilities are comparable.
Heterogeneous multi-agent system	Entities with various roles, characteristics and knowledge databases. They are created for the purpose of performing various tasks in the community in which they reside. Their task is to cooperate to achieve defined goals.

Source: own work based on [4]

The application of the first and second types 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 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 [16]. It can be noted that typical knowledge management systems make users' knowledge available in the form of documents and links to specific knowledge resources. Usually researchers [13] 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 he/she encountered. For instance, how the process in which he/she 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 [24]. In the case of teaching processes, in particular Intelligent Tutoring Systems or Learning Management System [23], 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 [14] which is designed to achieve the goal of knowledge building [23]. In this situation, a chatterbot allows the user to obtain the answer to the problem he/she encountered. 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 [1]. 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. First, this results 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 knowledge management systems 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 point 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 knowledge management systems and as an element of the architecture of such a system. Such solutions are implemented in an organisation, for instance, to support software management processes [19], support Call Centre systems [21], [2] where information systems are used in the process of data search using SQL language or [28] to support a consulting company. While such solutions support specific elements of the life cycle of the knowledge management system, 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, and [18] points out the necessity to perceive software agent societies as an element supporting knowledge integration in an organisation, 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 [8]. 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 knowledge management systems and business processes, one can indicate such solutions as [12], which address the problem of integration of common or Business Intelligence [22] applications within knowledge management systems.

The concepts mentioned earlier show 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 point 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 knowledge management systems, the task of software agents is to provide the participant with appropriate knowledge, which is required in the context of the process in which he participates and the task he performs.

In this case, agent supported solutions integrating KM and BPM 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 knowledge management systems 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 knowledge management systems and a process-oriented solution.

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

3. SYSTEM PROPOSITION

This chapter 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 modeling. The subsequent chapter will present an example of using the architecture for modelling a business process and defining knowledge resources used in it.

3.1 SYSTEM FUNCJONALITY INTRODUCTION

The aim of the solution developed 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. The system itself also has its own multi-agent system, which is used in the process of analysing gathered knowledge and its codification by means of semantic mechanisms. This paper will present a fragment of its functionality in the area of modelling business processes in BPMN along with the adopted artefacts extending its functionality and the use of a mechanism for evaluating interface agents (chatterbot) in performing the user's tasks.

3.3 SYSTEM ARCHITECTURE

The research into the cooperation of knowledge management systems, systems supporting business processes of organisations and agent technologies resulted in the development of a system architecture that consists of seven layers (figure 3).

<table>
<tr><td></td><td>Layer 1. Users</td><td rowspan="2">The layer of personalization and communication</td></tr>
<tr><td rowspan="2">The layer of management of knowledge portal</td><td>Layer 2. Knowledge portal and chatterbots</td></tr>
<tr><td>Layer 3. Business Process</td><td rowspan="3">The layer of management of software agents society</td></tr>
<tr><td></td><td>Layer 4. Agent Evaluation Tool</td></tr>
<tr><td rowspan="2">The layer of knowledge sharing</td><td>Layer 5. Multiagent System</td></tr>
<tr><td>Layer 6. Ontology</td><td rowspan="2">The layer of knowledge storing</td></tr>
<tr><td></td><td>Layer 7. Database Layer</td></tr>
</table>

Figure 3. Layers of an agent system for supporting knowledge management in an organisation

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 an organisation is acquisition of certain knowledge. This however does not result from willingness to learn, but 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 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 architecture developed 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 knowledge management systems indicated in 2.2.

Layer 3 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 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 knowledge management systems are linked with an organisation's business processes. Figure 4 shows an example of a business process modelled in BPMN in an IT system supporting business processes of an organisation and its representation in the tool developed.

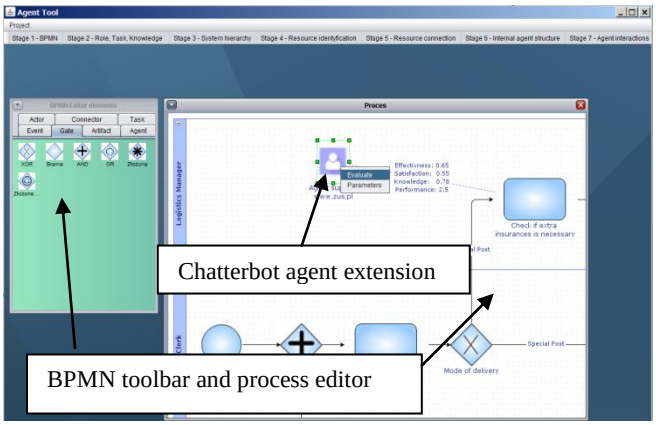

Figure 4. Proposal to extend business processes by new knowledge resources

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 which they participate. The main artefacts extending the functionality of BPMN as indicated in the figure above have been presented in table 2.

	Interface agent - designates possible applications of an interface agent as an element supporting the performance of a specific task by the user. It allows the user to go into the mode of evaluation of an agent's usefulness and use it to support the user's actions.
	A multi-agent system - designates a possible application of a multi-agent system to substitute the user or prepare a specific knowledge resource that will be necessary in the decision making process.
	Knowledge resource - designates a specific knowledge resource in knowledge portal or the Internet that can be indicated to the user. It can be a document, web service, URL identifier.
	Consultant - designates a specific person who has the relevant knowledge about the performance of this task. The process of selecting a person to perform specific tasks has been presented in paper [28].

Table 2. Applied artefacts extending BPMN

The use of such artefacts makes it possible to contextually connect knowledge resources of an organisation within a specific process and task. This shortens the time it takes for 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 5 presents an interface of access to knowledge resources of a knowledge management system in the context of the process and task shown in figure 4.

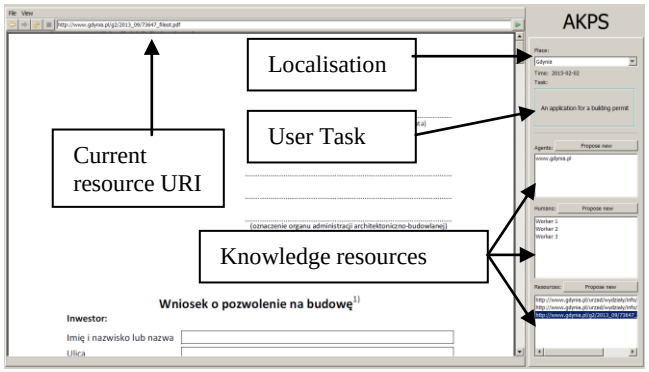

Figure 5. Interface of access to knowledge resources

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

The next solution is a tool for evaluating an agent's usefulness, which constitutes **layer 4 of the architecture developed.** This tool makes it possible to interactively define a template for evaluating the usability of an interface agent and define 4 parameters of the operation of an agent: effectiveness, performance, satisfaction and knowledge sharing [15]. 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 (figure 6).

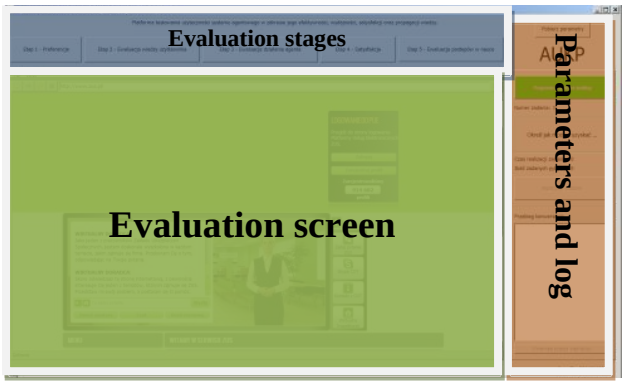

Figure 6. System for evaluating the process of assessing an agent's usability

As shown in point 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 analysis of any chatterbot agent published in the Internet. During evaluation of an agent, the user is informed on an ongoing basis 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 [15]. This is important, as it may turn out that despite its broad knowledge the agent doesn't support appropriately specific tasks. In such a case, it would be necessary to update its

knowledge database. Also, its knowledge may become obsolete. Mechanism defined in this way make it is 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 7).

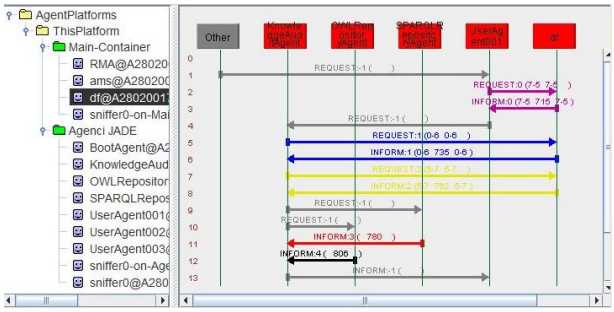

Figure 7. Elements of a multi-agent platform

The architecture developed includes:

- BootAgent - 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 - agent responsible for the process of analysing the knowledge of the system. It generates usability indicators for the different knowledge resources.
- OWLRepositoryAgent - agent responsible for the process of maintaining the knowledge database of the platform.
- SPARQLRepositoryAgent - agent handling SPARQL database of queries concerning the knowledge database of the platform.
- UserAgentXXX – instance of a user agent generated during the operation of the platform.

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 8.

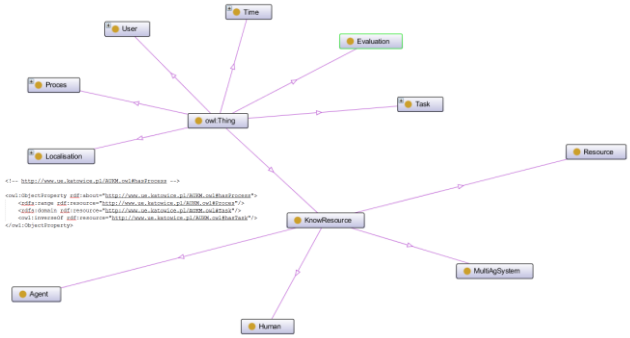

Figure 8. Part of prepared OWL ontology (main concepts)

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 possessed organisational knowledge and is consistent with the concept of WEB 3.0. It also contributes to 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.

The last layer 7 is the most technical and refers to the applied system for database management which enables integration of data from any source and its processing.

4. EXAMPLE OF 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 a 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. This process is presented in figure 9.

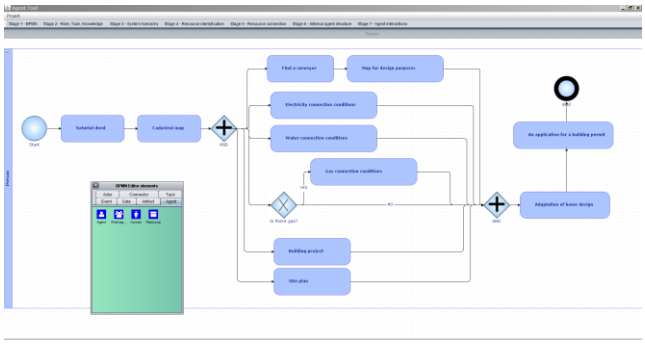

Figure 9. Process of obtaining a planning permission.

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. Also places of their storage will vary. Therefore, the process illustrated in figure x, though correct for a specific person, is general and for reference only. The application of the solution proposed makes it possible to extend this process by the context of its use including place and

time and knowledge resources that can be used, which is presented in figure 10.

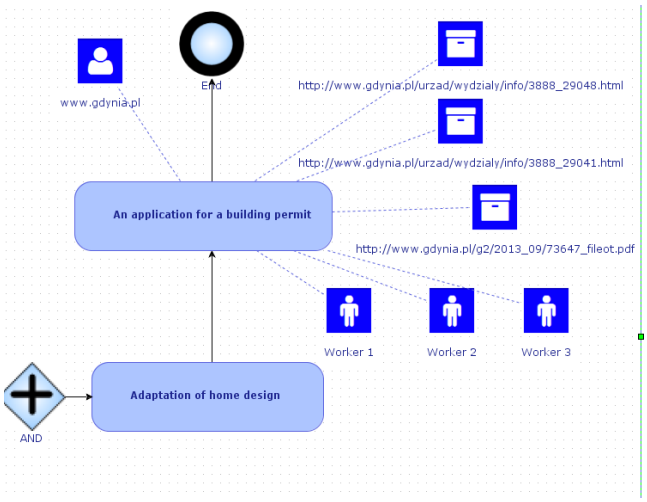

Figure 10. Extended process of obtaining a planning permission.

As a result, the person performing such a process may become equipped with additional knowledge on its course and the source of this knowledge. He/she 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 whe ther to use it or not.

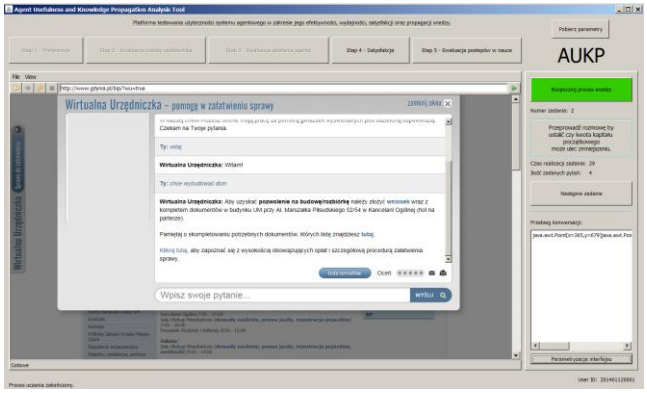

Figure 11. Chetterbot evaluation process on www.gdynia.pl portal

Based on the interface of evaluating an agent's knowledge(figure 11), 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 as follows (figure 12).

```
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
```

Figure 12. The algorithm of the process of analysing the agent's usability based on OWL concepts (performance parameter)

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 13). The user may also use other knowledge resources that have been assigned to a given process.

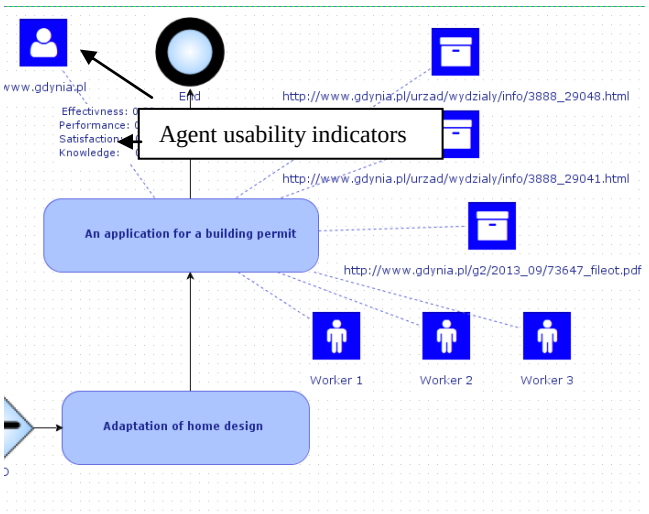

Figure 13. Preview of agent usability

And assign new knowledge resources to the process (figure 14),

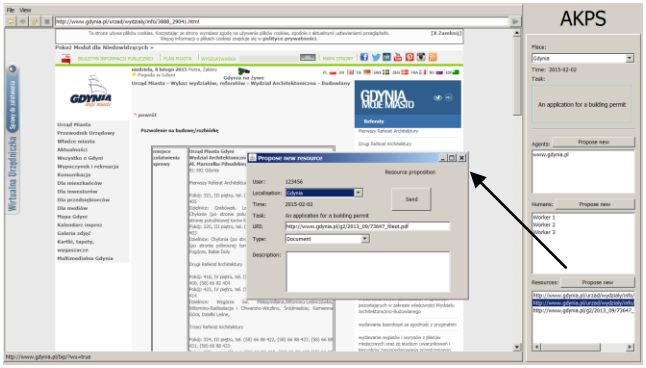

Figure 4 The process of assigning knowledge to a process by the user.

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.

5. CONCLUSIONS

This paper addresses the issue of modelling agent-supported systems designed to integrate knowledge management systems within business processes performed by an organisation and its environment.

The solution proposed enables integration of various agent solutions within modelled business processes regardless of the level of agent socialisation indicated by V. Dignym

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.

Current research into 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 a tool supporting the modelling of such solutions will be the subject of the author' further research.

6. ACKNOWLEDGMENTS

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