

# Modelling of Software Agents in Knowledge-Based Organisations. Analysis of Proposed Research Tools

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**Abstract.** The development of the theory of multi-agent systems in the area of their use to support an organisation can be examined in the context of supporting the performance of business processes and knowledge management processes that take place in modern organisations, in particular knowledge-based organisations. Agent technologies created in this area can be considered in categories of software agent societies, where a multi-agent solution is supported by mechanisms for analysing behaviour of such a system. The aim of this paper is to analyse research methodology and scientific tools developed during the three last years by a team of researchers in the specified field. The paper presents theoretical issues connected with the use of knowledge management systems in organisations, partial results of interviews with developers of agent solutions in Poland, a proposal of a methodology for designing agent societies, elements of a developed prototype of an agent solution, findings of qualitative research in the area of usability of software agents and assessments of multi-agent systems supporting knowledge management.

**Keywords:** Software agent · Agent societies · Knowledge management · Knowledge-based organization · Usability

## 1 Introduction

Development of organization's theory for modern forms of management of the company's action results in that solutions need to adapt their structure and functionality to meet the specific needs of the organization. One example is to look at the management-oriented approach to knowledge, which is seen as an important organization's resource. Such knowledge, perceived in the literature as an overt or covert knowledge, is an essential part of business processes that such organizations implement. Solutions, which according to the authors have the indicated characteristics, are agent systems.

The development of a theory of agent systems as an element of knowledge supporting systems in organisations requires that new concepts are constructed in the form of methodologies, methods and models that support designing, construction and

assessment of information systems of this type. Studies conducted over the last few years by a team of researchers enabled the development of a set of research tools to support the process of modelling software agent societies in knowledge-based organisations.

The studies conducted by the authors, initiated in 2012, on the modelling of a software agent society in organizations based on knowledge, were focused on the search for forms of use of software agents in the context of their use in modern organizations and determination whether these solutions, aided by semantic knowledge representation, contribute to the improvement of business processes. Due to their complexity, first an analysis of the literature in this area was conducted in order to arrange a society of agents in the registration system used in organizations [1–3]. Further, IT companies which offer agent-based solutions were asked to indicate their main problems with modelling and implementation [4, 5]. As a result, studies on currently used multi-agent platforms [6] and agent systems design methodologies [7] allowed the authors to propose a modelling methodology of a software agent society [8–10], its possible architecture [11, 12]. The second area of the studies was to develop a research method to assess the impact of software agents on participants of business processes. The studies presented in papers [13–15] enabled the development of a multi-stage research method to assess usability of software agents. The third element was the development of a trust and reputation model and indicators allowing trust and reputation to be assessed in an agent society. Results of these studies were presented in papers [10, 16–18]. The last element was the development of a method for examining a multi-agent system, which was used in the area of analysis of agent systems applied in e-health.

The elements of the specified research tools and results will be presented in this paper.

## **2 Knowledge Management in Organizations (Literature Review)**

The concept of knowledge management (KM) was developed to discover tools and methodology of management of knowledge, which was described as one of classical factor of production with land, labour and capital by Drucker [19]. The term of knowledge management is one of the most promoted and integrated approach to identifying, capturing, evaluating, retrieving, and sharing all of an enterprise's information assets. These assets may include databases, documents, policies, procedures, and previously uncaptured expertise and experience in individual workers [20].

Knowledge management system (KMS) is dedicated to help an organization to meet its goals and to increase its effectiveness. The literature review shows that a number of different definitions of knowledge management system have been proposed in the literature, and debates about this concept have been expressed from a variety of perspectives and positions [21–23]. Also there are some models of life cycle knowledge management in organization [24, 25]. Information and communication technologies (ICT) may play an important role in effectuating the knowledge-based view of the organization to manage the knowledge it possesses [20, 24]. KMSs are technologies that support knowledge management in organizations, specifically, knowledge

generation, codification, and transfer. Nowadays, modern ICT (interactive communication channels, agent oriented technologies, etc.) in a company due to the development of Web 2.0/3.0, i.e., social media, blogs, micro blogs, forums, wikis, and others, makes an impact in knowledge-based organization.

Knowledge-based organizations understand the importance of knowledge in the process of creating a competitive edge and focus on creating value added based on an effective use of knowledge [26]. ICT solutions focus on the aspect of supporting. Such organizations should support business processes that take place in them in the area of creating, processing and sharing a contextual knowledge about them. This results from the fact that knowledge-based organizations focus not only on business processes but also on knowledge management processes which should be treated in such organizations equivalently. Nowadays a knowledge management system is facilitated by Web-based ICTs. It is worth underlining, that the majority of companies use well known ICTs, for example: e-mails, online surveys, social networks, Internet forums, business blogs, comments posted on a producer website, business (specialized) portals, online price comparison [27–29].

One of the solutions, that can help such organizations, are software agent societies which can support the different stages of knowledge management systems life cycle [2, 30].

There are some models of life cycle knowledge management in organization. Some of the models refer to the first phase as knowledge creation, but Davenport and Prusak [24] use the term generate knowledge. The Turban's Knowledge Management Cycle [20] shows six steps of processes:

(1) Create knowledge; (2) Capture knowledge; (3) Refine knowledge; (4) Store knowledge; (5) Manage knowledge; (6) Disseminate knowledge.

The study shows the kind of models of agent supported organizations [1]:

- Information allocation model - an agent model refers to the way information flows between the organization and its environment, and additionally the influence of the information on the organization, using a software agent.
- The presence of authority's model - the participation of agents as the authorities in a decision making process relied on two features: modularity and decentralization.
- Organizational norms and culture model – an agent's behaviour depends on the organization's historical factors which are contained in the organization's norms and culture,
- Motivating model – the human factor can be subjected to various influences which in the case of the use of agent-based solutions come down to a certain decision imperative of an agent.

### **3 Methodological Aspects of Designing Software Agent Societies (Research Methodology)**

Studies conducted by the authors allowed them to develop research tools in the form of a few coherent concepts which may contribute to the development of modelling of software agent societies in knowledge based organisations. They include a concept of

methodology for modelling software agent societies, a trust and reputation model in a software agent society and a method for examining usability of software agents. The development of the specified solutions was preceded by a range of in-depth interviews with IT companies in Poland engaged in creation and implementation of agent solutions.

### **3.1 Software Agent Societies and Problems with Their Implementation**

Agent solutions currently available on the market are used to support the interaction between the human being and the computer. Studies confirmed this trend. The solutions created by respondents should be considered in the vast majority in the context of supporting knowledge management systems. Most of them can be examined in their role of interface agents that communicate with the user in a way that is closest to natural communication [31], along with their most important functionality of active participation in business processes using their own database of codified knowledge linked with an organisation's information systems. Studies conducted by the authors allowed them to analyse and compare the approaches of different vendors of agent solutions designed to support the improvement of business processes in knowledge based organisations. Among the solutions offered to the market in the use of agent technologies in the sphere of supporting business processes in organizations managed by knowledge, the vast majority are so-called "virtual advisors" showing, in accordance with the adopted typology, lowest level of socialization [32, 33]. The studies enabled identification of the tools used by vendors of agent solutions at the stage of their development. The researchers' attention was focused mainly on methodologies for creating agent solutions. The developers of the solutions under examination stressed that their methodologies for building agent systems concentrated mainly on the architecture of these systems, and only to a small extent enabled modelling of the knowledge of a system. This results mainly from the lack of reliable solutions that use a methodological approach to modelling semantic mechanisms of knowledge representation for the purpose of agent structures. Respondents were mostly in favour of the use of popular agile methodologies, which are typically applied in the creation of traditional IT systems. They mostly based their works on good practices, identifying their own methodologies dedicated to agent solutions. None of the sets of tools used by the respondents included methodologies focused directly on creating software agent societies. The process of identifying methodologies requires, on the one hand, addressing the issues of methods for creating software, while on the other hand, taking into account the theory of knowledge engineering, which is required in the context of modelling agents' knowledge database. Apart from the problems concerning methodologies, the respondents indicated the necessity to find methods for assessing the impact of solutions they created on the operation of the organisation itself and its environment.

Despite the lack of universal designing methodologies dedicated to the process of creating agent solutions, the process of implementing an agent solution by different vendors is similar. In simple terms, we can assume that this process comprises four main stages.

The process begins with analysis and gathering of information from the user to be later used to formulate knowledge of an agent. The fundamental problem at this stage is lack of structuring and a large diversity of sources from which the information comes. Information is most often gathered by means of individual interviews or is obtained as a result of searching through paper and electronic documents related to the user. The knowledge obtained as a result of processing received information is not always codified in a clear and comprehensible way, so it is often necessary to systematise it.

The second stage involves designing a model of obtained knowledge, systematising it and structuring into a form that is legible for an agent and allows it to identify a thread and provide the user with the right answers.

The next stage is the implementation of an agent system. The last stage usually involves testing of the system by the user and feedback about its functioning. Feedback from the customer makes it possible to assess whether the knowledge that has been fed to an agent is correct, complete, updated, whether the scope or substance of the knowledge has been somehow changed, and whether it is necessary to update the knowledge. Despite the lack of uniform formalised methodology and the use of own methodologies, companies rely on well-tried UML-based tools, which make it easier to model structures of databases, allow the structure of knowledge to be organised, relationships within the knowledge database to be described, and the architecture of agent systems to be designed. The range of agent solutions used in the process of creation is very wide. Apart from universal ones, such as: Enterprise architect, Power Designer, the respondents also mentioned such tools as: Eclipse, Semantic Works or Protege for building ontology. Companies also use CASE tools, which bring measurable benefits. Consistent use of such solutions at the company level guarantees maintainability of the system and good documentation of its architecture [34].

Despite the lack of official methodologies regulating the process of creating agent solutions, the respondents declared that the process of creating agent solutions in their companies was more or less in line with the model presented above. Undertaken actions are based on the common sense, are consistent and use necessary resources. In one case, the whole process of creating an agent solution was subject to corporate ISO procedures, which enabled the development of own methodology, that - though not consistent with any of the formally recommended methodologies - showed typical characteristics of agile methodologies. The solution used was fully formal (had documentation, its design contained established functions).

In the solutions examined, processes connected with knowledge acquisition were the most varied. As the respondents stressed, this resulted from the necessity to use individual methods and algorithms dedicated to specific customers and specific areas of application. The creation of such knowledge databases is very individualised. The implementation of knowledge databases that are based on ontologies is significantly hampered by the dynamics of changes in knowledge resources which occur in organisations. The volume of knowledge increases at such a fast pace that the time taken to update a knowledge database is longer than the period for which such knowledge is useful for the user. In such situations, a large repository of documents equipped with an advanced search engine is created instead of a traditional knowledge database. Knowledge acquisition is additionally hampered by insufficient level of knowledge possessed by organisations planning to implement agent solutions, by

unique character of the knowledge used in knowledge databases of agent solutions, complete or partial lack of structuring of this knowledge, problems with its clear articulation or concerns over unauthorised use of acquired knowledge. Frequent problems are difficulties with appropriate categorisation and systematisation of knowledge as a result of which it can take form of elementary, unique portions of information (facts, threads...). However, the biggest problem during implementation is appropriate interpretation of a given piece of information and its use in the right context, which is caused by high ambiguity of an agent's statements. Creation and use of appropriate designing methodologies in the processes of creating agent solutions should make the gathering of knowledge from the different areas more efficient, and appropriate structuring, clear codification and adaptation to a specific model of knowledge - easier. The next stage should be to unify the notation of knowledge and to create a common format that can be exchanged between different solutions.

After implementation of the solution, manufacturers attach great importance to feedback from the customer, confirming the correctness of topicality and completeness of the knowledge that was introduced to an agent.

With the increasing number of implemented agent systems and their complexity merits, there is a natural need to systematize the knowledge concerning the activities undertaken and their standardization. The use of established methodologies in the implementation of solutions is not disputed by principle, but the very process of implementing the chosen methodology is not carried without complications. Among the fundamental problems that arise in the implementation of methodologies indicated by the respondents two groups were dominating:

The first group of objective problems, connected with the necessity to increase efforts to introduce and update adopted methodological solutions as well as methods and tools designed to implement these solutions, often result from the lack of flexibility and other imperfections of adopted methodologies, which entails the necessity to create appropriate organisational structure and operational procedures.

The second group includes problems that are very difficult to predict and subjectively related to specific individuals connected with the life cycle of a solution, such as: fear of change, loss of autonomy, being accustomed to the existing, not always fully formalised, way of working, sense of redundancy of seemingly unnecessary documents required when implementing the methodology; they reduce the possibility of practical use of methodologies in current projects, and consequently hamper the maintenance of the solution implemented.

Lack of developers' experience in working on complex systems, specificity and complexity of reputed methodologies used during implementation of projects involving complex, partially autonomous, structures of software agent societies - all these factors increase methodological problems encountered during implementation of individual solutions.

The studies focused on the aspect of modelling agent societies conducted by the authors allowed them to identify a range of problems faced by the developers of solutions available on the market. This created a chance to propose a methodology that will improve the development of societies of software agents. Specificity, variety and complexity of software agent societies designed to support organisational processes in

an organisation managed by knowledge make it necessary to create a transparent and universal model based on respondents' long experience in creating similar solutions.

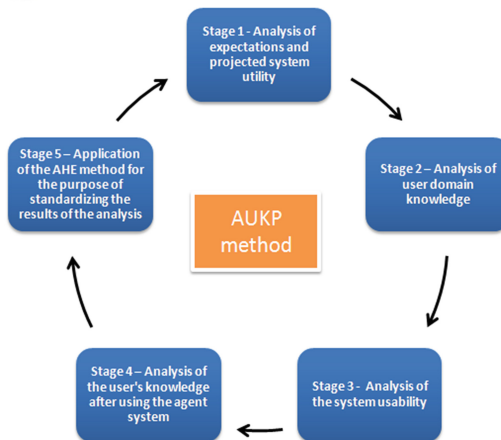
Conducted interviews indicated that currently created agent-based solutions offered by the companies relate to individual agent solutions. One of these aspects, that caused the lack of implementation in the area of multi-agent systems, was to identify the problems with the integration of knowledge abstracted within the agent system. Therefore, one of the research aspects was to develop proposals for taking up modelling methodology of software agent society in the context of highest level of agents' socialization, which will focus on the aspect of system's semantic knowledge codification methods and business processes organization. In order to develop such methodology, a number of multi-agent platforms [6] and methodologies [7] available in the literature and methods of agent design solutions [12] were tested.

### 3.2 Usability of Agent Systems

As part of the conducted qualitative research it was necessary to determine how software agent societies improve business processes in organizations based on knowledge. On the basis of the study, creators of agent solutions in Poland were diagnosed and a test method allowing for evaluation of the usability of agents in the context of human - computer interaction was proposed - AUKP - Agent Usefulness and Knowledge Propagation analysis method (Fig. 1).

During the tests of usability of software agents implemented in organizations, the analysis was conducted in the following stages [14]:

- Analysis of expectations and projected system usability. Aim: determine the expectations of the users in relation to the agent system and its functionality.



**Fig. 1.** Agent usability and knowledge propagation analysis method (Source: own research)

Proposed method: research survey analyzing the significance of the basic indicators of the system usability.

- Analysis of user domain knowledge. Aim: determine the user's base knowledge in terms of the domain aided by the agent system. Proposed method: survey of knowledge which the user obtains as a result of working with the agent system.
- Analysis of the system usability. Aim: determine the values of the specific indicators of the assessment of the system usability for the user and the organization. Proposed method: direct analysis of the agent system's operation.
- Analysis of the user's knowledge after using the agent system. Aim: to determine the user's knowledge in the field supported by the agent system after using the system. Proposed method: survey of knowledge obtained by the user as a result of working with the agent system (as in stage 1).
- Application of the AHP method for standardizing the results of the analysis. Aim: standardization of the results with regard to users' expectations for a comparative analysis of agent systems. Proposed method: application of the AHP method based on the results obtained in stage 1 and stage 3.

First, an analysis of previously conducted research on the human - computer interaction in the context of agent usability testing environments was performed. These studies have shown objectivity of examining the usability in terms of the agents' impact on the users. The assumptions concerning the developed method and the results of the conducted experiments are discussed in more detail in papers [15, 35, 36]. In these studies researchers assumed, that in accordance with the concept of usability, it is necessary to refer to the analysis of effectiveness, efficiency, satisfaction and propagation/dissemination of agent system's knowledge.

The aim of the above-mentioned research by the authors was to analyse agent solutions currently used on the Polish market using a proposed qualitative research method to evaluate usability and degree of knowledge distribution between the human being and the computer in terms of using agent systems. For this purpose, the process evaluation model for specified factors within the AUKP method was developed and 102 research experiments were carried out, the aim of which was to evaluate the operation of three software agents.

Agent A performed the function of a salesperson, and its task was to acquaint the user with the offer of products and functioning of the organisation. Agent B performed informational tasks; by substituting traditional hotline, it disseminated knowledge about social insurance, whereas Agent C supported the user in the area of the functioning of urban services for example through providing appropriate models of documents, directing to the right department, etc.

The experiment used multiple criteria, taking into account analysis of all pre-defined measures of usability, i.e. knowledge, usability, performance and satisfaction. It should be stressed that interface agents implementing various objectives and tasks were used in the experiment.

All tested software agents contributed to the improvement of the user's knowledge. The knowledge growth rate was above 0.7 for all agents. In the group of males and people over 25 years of age we observed a higher level of acquisition of the agent's knowledge. In the case of more simple tasks, people with lower education obtained



better results. More complicated tasks were better performed by people with higher education. What's interesting, the research showed negative correlations between the level of computer skills of users and their satisfaction with working with agents. Such correlations were identified in the case of agents A and C [35]. This shows that agent solutions are better perceived by people with poor computer knowledge for whom contact with an agent is more of a form of cooperation with other users.

The results also confirmed [35, 36], that in the group of users and agents it can be indicated that the agent-based solutions contribute to the improvement of business processes in which they participate by improving customer satisfaction and propagation/dissemination of knowledge among users regarding the organization and the processes, in which the organization and the business process recipient participate.

All aggregate results shown here revealed, that in the case where it is possible to identify high efficiency of agents and their productivity, users indicated high levels of satisfaction and knowledge gain. What is characteristic, increased productivity of agents and their effectiveness influenced the increase in user's satisfaction and the amount of knowledge they acquired.

### 3.3 Modelling of Software Agent Societies

None of the methodologies analysed [7] fully define an organization's ontology or social relationships. Only three of them do this in a limited way, where designer is usually able to define only concepts of agent ontology. Also the mechanism of agent's interaction with the environment is not well realized by the methodologies analysed. Comparative analysis, at the stage of the assumptions related to design of multi-agent system, indicated that the agent society, through the used methodology, will have limited functionality. The result of the study was to offer the methodology fully shown in the book "Agent technologies in knowledge-based organisations" [8].

This methodology was created as a combination of software agent society design good practice, ontologies design methods and BPMN notation used for the purpose of analyzing the requirements for the created agent society in the context of the organization it is supposed to support.

The proposed methodology consists of 8 stages, which include:

1. Analysis and development of business process
  - 1.1. Specification of organizations involved in the process and the posts performing the tasks.
  - 1.2. Determination of relationships inside the organization. At this stage, the relationship is defined within the organizational structure that supports the system. In the case of an organization, it is a structure linking the different departments and the process participants' positions.
  - 1.3. Defining the rules of starting and ending the process.
  - 1.4. Diagnosing the business process tasks.
  - 1.5. Diagnosing the business process events.
  - 1.6. Defining the conditions governing decision gates.

- 1.7. Determining the extent of an agent's support of a specific task (realization of tasks, assisting the task, none)
2. Identification of resources in an agent society
  - 2.1 Identification of inputs and outputs of the main task
  - 2.2 Identification of resources in the form of services or external data
3. Analysis of the roles and responsibilities of agent society
  - 3.1 Defining the tasks carried out in the agent society
  - 3.2 Defining the roles of agents in the system
  - 3.3 Diagnosing emergency situations (events)
  - 3.4 Defining the inputs and outputs based on events
4. Determining the hierarchical structure of the relationship inside the organization
  - 4.1 Reference of the organizational structure with the main tasks carried out by agents
  - 4.2 Determination of an organization's internal relationships within the agent society
5. Determination of the extent of agent societies' knowledge
  - 5.1 Identification of knowledge range of an agent society
  - 5.2 Identification of the resources provided by agent societies
6. Preliminary definition of agents' internal architecture
  - 6.1 Determining agent classes
  - 6.2 Assigning agent classes to roles
  - 6.3 Assigning agent classes to resources
7. Essential definition of the agents' internal architecture
  - 7.1 Agent knowledge specification
  - 7.2 Defining an agent's behaviour
8. Designing the interaction between agents

The proposed approach for an agent society modelling is considered in terms of the heterogeneous construction of agent societies and determines the combination of best practices for agent solutions modelling to support business processes within the organization's information systems. In particular, this methodology is dedicated for knowledge-based organizations through its focus on modelling of the organization's knowledge using semantic mechanisms of representation.

The proposed methodology has been developed upon the experience regarding the developed prototype of agent-based solutions supporting the operation of the organization and developed in the context of building solutions supporting the interaction of users within the business processes in which they participate [11].

The methodology proposed in the context of creating software agent societies was extended to include a model of analysing trust and reputation of agents.

### 3.4 Model of Trust and Reputation in a Society of Software Agents

Software agent societies in the aspect of a multi-agent system require the use of mechanisms for controlling the behaviour of agents in the system. In this area, the authors conducted literature studies and developed assumptions of a trust and reputation model in software agent societies. Results of these studies were presented in papers [10, 16, 17]. The aim of the model proposed by the authors was to show how it is possible in the case of autonomous software agents to control and analyse their behaviour in a society and to select agents for the implementation of specific tasks as part of business processes in which they participate. For that purpose, three areas of the model being created were distinguished in the studies:

- The area of an agent's own trust, which referred to analysis of own behaviour in the context of participation in business processes.
- The area of trust in actions of other agents in the society, connected with the assessment of the behaviour of agents remaining in the environment.
- The area of reputation in the society of software agents connected with sharing knowledge about the trust in agents in the society.

The areas defined and analysed in this way were divided according to a hierarchy resulting from a process view of the society under examination, which reflected the adopted methodology for designing such a society. The levels of the hierarchy analysed included:

- The level of the whole society.
- The level of a business process.
- The level of a task performed by an agent.
- The level of an action undertaken by an agent.

The research experiment conducted and described in paper [17] and the proposal of indicators showed a possibility of using such a solution in the area of building self-organising societies of software agents. The trust and reputation model proposed is still being developed. One of the areas in the development of the specified model is the use of AHP method for the purpose of assessing the operation of software agent societies [38].

### 3.5 The Research Model of Multi-agent Software in a Knowledge-Based Organization

There are different functionalities of knowledge management in this kind of agent supported knowledge-based organization, e.g. in business context [39], human capital management (HCM) context [31], health care context [40], etc.

In the context of HCM, we can see solutions consisting of task-specialised and cooperating software agents that form multi-agent systems (MAS), and within them there are specific societies of "HR agents" focused on the different HR processes taking place in an organisation [40, 41]. These systems support, in particular, processes connected with recruiting, creating and maintaining human capital in an organisation.

Multi-agent systems in HCM search for and process knowledge connected with employees' competence profiles, their development, career paths, the process of improving skills, trainings and self-improvement.

In the context of health care, MAS may play an important role in effectuating the knowledge-based view of the e-health organization by enhancing the capability to manage the knowledge it possesses [5, 32]: knowledge about the patient, knowledge of the presented medical problem, contextual knowledge about the course of the conversation in e-health, knowledge of the e-health organization.

The research model of multi-agent knowledge management system in healthcare is based on [43]: knowledge creation about the user, knowledge sharing of the presented problem, contextual knowledge about the course of the conversation during knowledge distribution, knowledge application in the organization.

There is a diversity of areas in medical industry and health care systems that could benefit from systems based on agent technology (especially MAS) [32, 33].

Nowadays, e-health area is one of the fastest growing sectors worldwide. It is worth mentioning, that healthcare units have to implement efficient knowledge management in order to provide high quality services and reduce unnecessary costs. Usage of computer science, Internet and other modern technologies give these opportunities. One of technologies of this kinds that could be helpful in healthcare is agent technology [43]. There are many examples of multi-agent systems (MAS) connected with healthcare [37], and human capital management. In healthcare, there are four main categories of MAS:

(1) Assistive Living Applications, (2) Diagnosis, (3) Physical Telemonitoring, (4) Smart-Hospital, Smart-Emergency Applications. In the second area, the most prevalent are applications based on interface agents that support communication and consulting processes. An equally important area supported by this type of solutions is the improvement of employees' skills, self-improvement and training processes designed to increase the value of human capital in an organisation. However, there are also theoretical and practical discussions highlighting the role of software agent societies in other HR processes. The main areas of such applications include: searching for employees, managing employees' competences at the stage of selection and management of career paths [40]. In these processes, it is necessary to use both societies of agents that acquire knowledge from an organisation's resources and societies of agents that search through a whole range of external sources containing information concerning candidates and trends on the labour market. The knowledge acquired in this way enables creation of knowledge databases, which are used to support HCM processes in an organisation. This model of knowledge processing is in line with Turban's classical model [20].

There is also an evaluation method of multi-agent software for knowledge management systems. The method of evaluation of multi-agent software (MAS) for knowledge management (KM) is based on some areas of knowledge management systems due to Turban's Knowledge Management Cycle [32]. The method of evaluation of MAS for e-health KM was based on four main phases of knowledge management cycle: (1) knowledge generation (acquisition, creation), (2) knowledge storage (capturing, refinement), (3) knowledge distribution (transfer, sharing) and (4) knowledge application (dissemination, utilization).

The findings show the critical factors of usage of a multi-agent system in healthcare in each phase of the knowledge management cycle, which are divided into four different categories [32]:

1. Content management tools: Tools that offer abilities to integrate, classify, and codify knowledge from various sources for e-health organization (knowledge of the health organization).
2. Knowledge sharing tools: Tools that support sharing knowledge between people or other agents in an e-health organization (knowledge about patients, etc.).
3. Knowledge search and retrieval systems: Systems that enable search and retrieval and have some knowledge discovery abilities (knowledge to solve the medical problem).
4. General KMS: Systems that propose an overall solution to a company's knowledge management needs (contextual knowledge about the course of the conversation).

## 4 Research Findings

The developed research tools for modelling software agent societies represents a set of tools that can be used to design and assess software agent societies.

The main characteristics of the proposed methodology for modelling software agent societies are: focus on business processes of an organisation (in the phase of defining system requirements), focus on processing an organisation's knowledge (both in the area of knowledge modelling and knowledge flows between the society of agents and an organisation's IT systems) and focus on the use of software agent societies in an organisation. The approach proposed herein offers the following advantages:

- 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.
- Operation independent from the used IT solutions and possibility of integration of any knowledge management systems and a process-oriented solution.

The use of 3.3 methodology enables the development of a model of an agent society that can be extended to include the proposed trust and reputation model.

The proposed trust and reputation model is dedicated to supporting the analysis of the behaviour of software agents in the context of their use to support operations of an organisation and refers to building autonomous, self-organising societies with mobility features. The main features of this model include:

- Focus on building a trust and reputation model based on a defined methodology for modelling agent societies.

- Focus on a specific multi-agent platform, i.e. JADE platform.
- Business orientation connected with the assessment of agents' actions in the context of performing business processes of an organisation.
- Hierarchic structure of the parameters of the trust and reputation model, which means that in the case when it is not possible to estimate the value of the model, the actions of an agent can be supported by more general indicators.
- Possibility of using this model in the context of building agents with mobility features, where information about agents' trust and reputation is shared among different agent societies.
- Possibility of using the proposed model in the context of security of a multi-agent system.

The model refers to agents' mutual impact on each other. In the context of using software agents as an element of a business process, it was necessary to develop a research method for assessing usability of software agents in the area of their use to support activities of an organisation. For that purpose, a range of proposed methods for examining the impact of agents on their environment were analysed, in particular in the area of HCI, and a research method was proposed that enabled classification of a range of indicators describing the operation of software agents and their impact on users. On this basis, qualitative research (in the form of experiments) was conducted to analyse the impact of software agents on participants of business processes. The characteristics of the research method proposed included:

- Focus of the analysis of agent usability for business processes of an organisation.
- Possibility of analysing efficiency, effectiveness, satisfaction and knowledge propagation in the context of agents' impact on participants of a business process.
- The development of a mathematical research model that can be further developed to include other indicators.

The research conducted on the Polish market by proposed AUKP method explicitly pointed out that from the perspective of the end user, agent systems that are part of an organization's information systems are considered useful by the users.

The experiments performed also allowed for some observations which were not a direct aim of the study: (1) errors resulting from human - agent communication, such as users' misspelling and the use of an agent incompatible with its purpose. (2) In addition, in users who have committed themselves to collaborating with an agent in this experiment, we observed a gradual increase in confidence and interest in this form of cooperation within the human – computer system. (3) Users' impression that they have obtained the necessary knowledge during the study has not been confirmed by the actual growth of knowledge in individual cases. This opens a field for further research. What's interesting, the research showed negative correlations between the level of computer skills of users and their satisfaction with working with agents, which leads to the conclusion that agent solutions are better perceived by people with poor computer knowledge for whom contact with an agent is more of a form of cooperation with other users.

Specialist applications of multi-agent systems, e.g. in the area of HCM or Health-care, enable free use of a wide offer of potential knowledge sources. Specific

conditions of these areas of application often make it necessary to implement additional mechanisms. For instance, societies of agents that support recruitment processes allow competence profiles of candidates to be found quickly. However, the variety of information sources, methods for the analysis of candidates and the variety of candidate profiles found by the different agents inevitably lead to conflicts between agents within a society. If a knowledge model has been properly constructed, it is possible, thanks to the use of argumentation-based negotiation techniques, to prevent most conflicts. In cases when it is impossible to build appropriate rules or the knowledge contained in them is insufficient, a vertical architecture of multi-agent systems can be used, and in cases when the negotiation process between the agents has not produced a solution, the agent supervising the course of process will choose the solution to the problem on its own. The findings also show the critical factors of usage of multi-agent software in healthcare knowledge management system in four categories: knowledge of the health organization, knowledge about the patient, knowledge to solve the medical problem, contextual knowledge about the course of conversation in KMS. These factors are connected with abilities of a multi-agent system to integrate, classify, and codify knowledge from various sources for e-health organization, sharing knowledge between people or other agents in e-health organization, and other abilities of multi-agent system to solve the medical problem.

## 5 Conclusions

Modern organisations using knowledge management systems to support performed business processes require the use of dedicated IT solutions that support these activities. In particular, they require the development of methodologies, methods and models that support their development and evaluation. The paper presents research findings and proposed research tools developed over several years of research into modelling of software agent societies. In particular, it reveals the findings of qualitative research conducted in the form of interviews in Polish companies engaged in the creation of agent systems, presents elements of a designing methodology focused on supporting the modelling of software agent societies, indicates research method and findings of research into usability of agents and elements of a trust and reputation model, which can be applied in the process of supporting the operation of software agent societies.

The elements of the research tools presented herein enable the development and evaluation of agent systems in organisations, in particular in knowledge based organisations, in which organisational knowledge is one of the resources. Therefore, the elements of the proposed research tools mainly address the problem of modelling and analysis of knowledge that can exist in such organisations.

With reference to the research methodology developed, further research will concern the construction and development of a tool designed to support designing of software agent societies in accordance with its assumptions. In the case of the method for examining usability, further research will concern its development towards analysis of not only usability but also ergonomics of software agents. In the context of the developed model of trust and reputation, research will concentrate on the aspect of its use with reference to mobile agents operating in numerous agent systems.

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