Information Coordination Using Meta-agents in Information Logistics Processes

Mats Apelkrans and Anne Håkansson

Jönköping International Business School, Department of Informatics,
Jönköping, Sweden
Mats.Apelkrans@jibs.hj.se
Department of Information Science, Computer Science,
Uppsala University, Uppsala, Sweden
Anne.Hakansson@dis.uu.se

Abstract. In order to coordinate and deliver information in the right time and to the right place, theories from multi-agent systems and information logistics are combined. We use agents to support supply chain by searching for company specific information. Hence, there are a vast number of agents working at the Internet, simultaneously, which requires supervising agents. In this paper, we suggest using meta-agents to control the behaviour of a number of intelligent agents, where the meta-agents are working with coordination of the communication that takes place in a supply chain system. As an example, we look at a manufacturing company receiving orders on items from customers, which need to be produced. The handling of this distributed information flow can be thought of as an Information Logistics Processes and the similarities of the functioning of processes and intelligent agents' behaviour are illuminated.

Keywords: Intelligent agents, Meta-agents, Multi-agent systems, Information Logistics, Supply chain.

1 Introduction

The goal for manufacturing companies is to deliver the right products in the right time with good quality to be competitive. This requires good planning, optimized purchases and well functioning distribution channels. It also requires an efficient handling of the information flow in the company. One of the problems in Business Informatics is the coordination of the information flow between the manufacturing company, its customers, and its suppliers. The goal of this coordination is to find a more efficient product manufacturing process. Information coordination between the actors should speed up the information exchange and, hence, optimize the production cost. Our approach is to combine theories from Multi Agent Systems (MAS), meta-agents and Information Logistics in order to coordinate and deliver information at the right time and to the right place at an acceptable cost.

To enforce qualified information management and provide the right information at the right time, we apply a multi-task system using multi-agents performing these tasks in parallel, which can handle a large number of tasks faster. In this paper, we study

I. Lovrek, R.J. Howlett, and L.C. Jain (Eds.): KES 2008, Part III, LNAI 5179, pp. 788–798, 2008.

the information flow needed in a manufacturing company to fulfill their order stock. In the production process, a major issue is the double directed information flows, one from customers to company and another from company to its suppliers. This information can concern orders, requirements and production plans.

In our work, we use intelligent agents to take care of different tasks in the information flow. Each agent's behaviour can be thought of as an Information Logistics Process (ILP) handling information between several sources with given input and output. Still there is a need for coordination of the intelligent agents' performances in order to fulfill the global task of controlling a successful company. The solution is using meta-agents. The use of meta-agents on top of the information flow chart can monitor the action of the intelligent agents and be used to control the information passing between the agents. The meta-agents can provide the users with requested information. An examination of the behaviour of an intelligent agent shows that it can perform as an ILP. Hence, there will be a number of ILP calls. The ILP is managed in overall strategy by the use of meta-agents. Each ILP has to meet the demands on e.g. time, content, and presentation.

2 Related Work

The ILP approach has been used in a number of test cases. One example is handling of content management problems [1]. These ideas were further developed using visual modelling of the e-invoice process [2]. Moreover, the work concerning ERP configuration was of a more surveying perspective i.e. to choose the right ERP implementation for a given company, hopefully, lasting for a number of years [3]. In this paper we like to make the right decision in a short time (dynamical) perspective. Looking at the business process perspective many papers are written in order to optimize the work-flow in a manufacturing situation [14]. However, these contributions do not include ILP. Our test case is more on the decision side, i.e., choosing the right solution to supplier problems to the best cost and at right time.

3 Information Logistics

The concept of Information Logistics (IL) has been discussed for a number of years and a number of definitions have been established. A recent definition is [16]:

"The main objective of Information Logistics is optimized information provision and information flow. This is based on demands with respect to the content, the time of delivery, the location, the presentation and the quality of information. The scope can be a single person, a target group, a machine/facility or any kind of networked organization. The research field Information Logistics explores, develops and implements concepts, methods, technologies and solutions for the above mentioned purpose"

It is possible to consider IL as a process that manufactures an information product and, hence, to introduce thinking from the production area, like Just-In-Time (JIT). Information Logistics could be defined as the discipline [2]:

- that will supply the right information at the right time, in the right shape and at the right place
  - in a user-friendly way
  - with desired quality
  - to the lowest possible cost in where the final product is distributed by some kind of information carrier like paper, card, CD, Smart Card, Internet.

It is easy to pinpoint a number of differences between ordinary logistics and IL. The information supply in ordinary logistics is essential and often time consuming and expensive. Much effort must be taken in order to handle inbound logistics, checking deliveries or out-of-stock problems or damaged materials. In IL stock replenishment, there is no problem. It is just make a new copy of the information product.

Looking at Information Logistics from a process perspective, we can see that an information logistics process transforms a given input into some form of output. The input is some kind of fragmented information or knowledge description, which is derived from a so-called information supplier. This input information can be handled, either manually or automatically, by the system. The process output is an information product that becomes accessible and delivered to the information receiver who can make use of the information. This workflow is called the Information Logistics Process (ILP). The input to the ILP comes from the application and the receiver can be either a new ILP or a database or system user. From the input the ILP communicates with the knowledge base to produce a desired output, see Figure 1. We can request the system to send output information as messages.

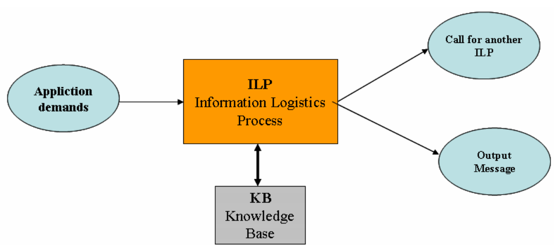

Fig. 1. The Information Logistic Process (ILP)

There are methods and discussions of ILP in the literature, where knowledge is applied in the ILP to support sending e-invoices between companies using external network [2] but also to automate configuration of enterprise systems [3].

The ILP processes are implemented with different methods found in the computer science area. Simple ILP processes are just straightforward database solutions; others need real-time machinery in order to deliver the information product at right time to the right place. Real-time components can, e. g., handle time management and communication details to facilitate the distribution of information to right place in right time [7]. Still others need knowledge management. A question is what can possibly be automated and what will still be contained in the dialogue between users of ILP and the ILP process. The ILP processes have to handle knowledge, or more properly, expressions of knowledge descriptions.

There are similarities between an ILP and the behaviour of an intelligent agent. Both concepts have the ability of communicate with others, produce messages in an intelligent way, and to send a message at right time. Hence, the use of intelligent agents offers a solution to the knowledge management tasks of an ILP.

4 Intelligent Agents and Meta Agents in Multi Agent Systems

Intelligent agents in multi-agent systems can be used to perform tasks in complex environments such as searching and retrieving information from sources and accessing services at the web. Some of the agents can work efficiently with commodity products, usually offering a list of products based on some criteria. Some of these agents can take actions on production process requirements and support assembling important information from several sources.

In logistics area, a multi-agent environment is needed since the tasks are too complex to be accomplished with one single agent. To our best knowledge, not many of the logistic agents work at the intranet and extranet, simultaneously, supporting information logistics process by supplying the process with external information. The extranet is extended to users outside the company and can support doing business with a pre-approved set of other companies over the network.

The agents must be capable of autonomous actions, situated in different environments [17] where some are intelligent and, thus, adaptable to the environment. The environment, i.e., the web, has some characteristics that the agents observe and act upon. The web is a vast network with over 100 million web sites where 74% are commercial sites or other sites operating at the .com. Hence, the environment is partially observable, stochastic, dynamic, continuous, and episodic.

In a partially observable environment only some of the information is known and therefore, can be a limitation. Environments such as the intranet and extranet are considered to be partially observable [17] because of its nature of continuously growth. However, the agents do not have to maintain their internal state to find satisfactory information. The agents, in our work, are working in the Information Logistics Process system to solve tasks, but also use the intranet and the extranet finding information. Either though we consider the environment to be partially observable, the agents must still able to find the significant information needed for finding solutions. Finding the necessary information corresponds to fully observable environment, where the agents can obtain complete, accurate and up-to-date information about the environment state [17]. The agents do not need to maintain any internal state to track the world and can easily achieve the task based on the information in the environment.

In a partially observable environment, the environment can appear to be stochastic [15]. The agent cannot predict the behaviour of the environment, as in real-world cases, since the state, which will result from performing an action, is unclear. Even though the environment is deterministic, there can be stochastic elements that randomly appear. A partially observable environment with stochastic elements is what will be expected for our agents. The agents have a task of searching and combining data but the information and combinations will vary with time, i.e., when actions these are performed.

A dynamic environment [17], the environment can change while agents are deliberating its contents [15], which is beyond the agents' control. In these dynamic environments, the agents need to interact with the environment and continuously check the surroundings to act properly. This characterises the intranet and the extranet since these change on a daily bases. However, the environment might be static over smaller time intervals, thus, remaining unchanged while the agents consider their course of action between states. Nonetheless, we will consider continuous changes, which will affect the agents and make them monitor changes during each task.

In continuous environments, there might be uncountable many states, arising from the continuous time problem [17]. Continuous time can be a problem for the intranet and the extranet agents because of the number of states and actions. This requires special treatment of the agents using an execution suspension to control the agents' performance. A common suspension of execution occurs when the agents have found information and returned with result. This limits the possibility of finding several solutions. A better solution in our system is an execution suspension for a short time interval followed by a resumption of the search.

In an episodic task environment [15] the choice of action in each episode depends on the episode itself. The agents, in our work, perform one task at the time while moving between commercial sites finding information. The task itself can be more complex, but before it is assigned to agents, the task is divided into smaller, single tasks, where each task is applied to an agent. In multi-agent systems for information logistics, a lot of intelligent agents will be used to perform a task, which in complex task environments will require a vast number of the agents. In these cases, meta-agents can be used to keep track of all the agents and their results produced from accomplishing tasks within acceptable time-range.

The concept of meta-agents is based on the idea of meta-reasoning. Meta-reasoning is a technique that supports the system to reason about its own operation. This reasoning can be used to reconstruct the agents' behaviour [13], but also to help in the interaction among agents. The meta-reasoning can be applied in the implementation strategies or plans to respond to requests [6].

Besides reasoning the meta-level agents (so called meta-agents) can plan actions and maintain individual agents' state information but also attempt to control future behaviour, classify conflicts and resolve these conflicts [5]. Another benefit with meta-agents is that they can work with intelligent agents in network to control and guide the performance [11] but also calculate the optimal decisions based on the intelligent agents performances in the time-dependent characteristics in the environment [10]. For our work, it is interesting to use meta-agents to combine different information pieces and calculate and select the best option for company on the basis of predefined features. Thus, evaluation is important since the results from the intelligent agents must be compared to find the best result that is most useful for the company.

Moreover, using strategies and plans to either look for information at the intranet or the extranet is important. There might be a mix of the searching, which arises when the information is not found at the intranet. Then the agents need to redirect the work to the extranet. The features of the meta-agents are applied in our system to support information flow in the information logistic process.

5 Information Flow Around a Manufacturing Company

The example company we like to study in this paper produces goods that are assembled from a number of items, some of them manufactured at place and some of them bought from different suppliers see Figure 2.

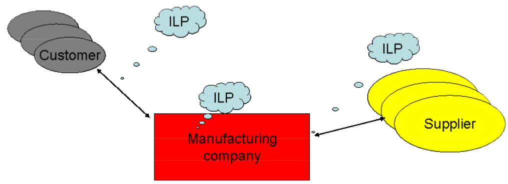

Fig. 2. The example company and its surroundings; ILP is Information Logistics Processes

As mentioned above, a lot of the information flow in the system consists of messages, some of them are input(s) to an ILP and others output from ILP directed towards a final goal or another ILP. Some examples of messages are:

- "Buy 25 pieces of item #1234 to best possible price with delivery not later then xx-xx-xx"
- "Take care of a new order of 30 pieces of item #2345 which should be delivered yy-yy-yy"
- "Check inventory for pieces of item#3456"
- "Tell customer ABC that his order is delayed 4 days"

Specialized intelligent agents that fulfill special tasks at right time can cover the behaviour of the ILPs. Thus, we can look at them as a simple information searching engines traveling between parts in the information flow systems, where the intelligent agents (IA) are solving the ILP information problems. This is, in fact, a multi-agent system and, in order to get useful solutions, their global effects have to be controlled by a number of meta-agents, which have the over all strategy for a controlled solution. Much of a manufacturing process is conducted by information stored in a database, hence the ILP have to communicate with a number of registers like:

Customer records
Supplier records
Load Planning
Returns Management
Product description with drawings
Price lists

The messages examples given above are not quite realistic since they are simplified in their task nature. In fact the intelligent agents have to penetrate much harder tasks like:

- Find out how to manufacture a product ordered from a customer
- Plan the master schedule
- Calculate Bills of material
- Produce Buying lists

For these different tasks both intelligent agents and meta-agents are applied. The intelligent agents work with information between customers, the manufacturing company and suppliers. The meta-agents work with monitoring and controlling the intelligent agents, and also accepting and combing information for optimal purchases for the manufacturing company.

6 The Multi-agent System

In the multi-agent system, the intelligent agents and the meta-agents have several different tasks. The intelligent agents' tasks are searching for suppliers of material and finding material according to pre-decided attributes for purchasing the raw material suiting optimal conditions. Additionally, the intelligent agents are keeping track of the material and the attributes. The meta-agents' tasks are combining information based on the results of the intelligent agents. Moreover, the meta-agents are planning manufacture, calculating the total cost of the manufactured product but also producing lists and plans. Furthermore, the meta-agents keep information about time delivery and records about the customers.

The process starts with customers ordering manufactured products. The orders are handled by the system, where each order becomes a planned action. The action launches the production line, which will begin to look for the parts and amount of pieces used in manufacturing. Each time a part is needed, the multi-agent system is invoked and the intelligent agents and meta-agents are activated.

As an example, let´s look at an order from customer ABC on 500 pieces of end-item #1. An intelligent agent finds the corresponding Bill of materials (BOM) which describe the "parts list" of components needed to complete a saleable end-item. The result can be 1500 pieces of item #1234, 1000 pieces of #2345 and finally 500 pieces of items #3456 and #4567 each.

In the case of suppliers, the intelligent agents search for information at the intranet or the extranet depending on the requested part. The intelligent agents move between the manufacturing company and the different suppliers, offering the parts for sale, and ask for information about the particular part. If these suppliers are subsidiaries, the agents are looking for information at the intranet, otherwise, at the extranet. Intranet is used when the agents need information from the warehouse of the manufacturing company.

When the intelligent agents identified all the suppliers offering the raw material, they need to find out the price for the pieces. Moreover, the agents need to know the amount of parts to order and find out if the suppliers have the parts in their stock or need to order these, in their turn. Also the price can change with the quantity and the agents must derive the price for the entire stock.

Finally, the delivery date is important. It is the supplier that sets this date but the agents need to consider the date and keep it stored. Moreover, if several customers want to buy the same product from the manufacturing company, the intelligent agents need to find enough raw materials for the product to cover the orders from all customers. This requires buying extra material from the suppliers and, moreover, might require buying the material from several different suppliers.

The results from the intelligent agents are compared to find the best options for the products. Moreover, commonly several raw material parts are needed to produce a product and all these pieces are important to assemble the final product and to calculate the delivery time to the customer. Since many intelligent agents are involved in the process, it is too complex to let them compare all the information about the raw material collected at the intranet and the extranet. Therefore, the meta-agents are applied to the intelligent agents.

The meta-agents correspond to goals of the intelligent agents. The intelligent agents work to find information on the parts and report to the meta-agents. Since many agents are involved, a strong part of the meta-agent needs to be a "reasoner" that evaluated alternative strategies.

As the information reaches the meta-agents, they need to select the best solutions based on the user-given attributes such as price, time, quantity, and quality. Hence, the user describes the attributes that the raw material needs to meet and the meta-agents have to combine these attributes to select the best option.

The calculation for the combination is complex. To evaluate the different attributes, they are given values within a range between 1-5, with the linguistic from of extremely significant to total irrelevant. The combination is then used together with the cost of the raw material to meet the conditions to the best possible price.

It has to be a balance of the cost, the material and the sacrifice of other aspects. For example, a cheap product may not be the best in quality and vice versa. Quality versus price raises questions, such as, is the quality of more important than the price and if so, what is the acceptable price for the material. Also time can be a cost for the company, which is why a slightly more expensive raw material can be acceptable for a particular production. Another aspect is quantity. If the company can buy a larger quantity, which might be more than needed for the manufacturing, they may get an offer that is price-worthy.

Except for keeping track of the amount of raw material, the meta-agents also need to keep track of the inventory of the pieces in the warehouses. The parts in the warehouse together with new material should barely cover the orders from the customers. Especially, for the companies that consider the importance of keeping the efficiency of lean production and reduce the stock in warehouses.

So far, we have only presented the process of finding information about suppliers for one part of raw material. However, in manufacturing, usually several parts are involved. The meta-agent needs to be the controlling agent, which holds information about all the parts that are being assembled. Thus, they need to direct the tasks of finding different suppliers for these parts to the intelligent agents. Then, from the results of intelligent agents, the meta-agents need to combine all parts to assemble the product and calculate the total cost and delivery time for the manufacturing. This combination is also used for planning the manufacturing.

To accomplish the search of all parts needed for manufacturing the product, information about the parts is essential. There are many ways to represent this information, such as, bills of material, frames and rules. For example: when the goal is to build a widget, we need to have a part-whole relation to describe the parts of the widget. Note, that a widget can be either information or a physical thing and that some widgets may have multiple possible parts. Either, it is possible to buy a set of parts to build a subassembly or buy the finished assembly.

Another important roll of meta-agents is to keep record of the customers. The meta-agents keep track of the information about the quantity of the manufactured products, the customer ordered. They also need to the information about requested delivery time of each product. Finding the raw material for all products, planning the manufacturing and calculate the delivery is a scheduling task for the meta-agents.

In the case of changes, such as the manufacturing, e.g., a broken machine that needs repairing, or the customer made changes in the order, the meta-agents need to react. The meta-agents have to take necessary steps to handle the situation, and depending on the problem, there will be different options. If they are machine problems, the meta-agents need to recalculate the delivery time. In the case of changed orders, they may redo the complete process from searching for the parts needed to planning manufacturing and scheduling the delivery. Another task for the meta-agents and Multi-agent system is to check the producing capacity. If a customer, for example, extends the order with 50 more pieces, the meta-agents have to check if the producer has sufficient capacity for the additional quantity. Capacity concerns both personnel and machines, and a suggested solution may be to delay delivery time a number of days.

6.1 Presenting the Information

An important part of the multi-agent system is to present the result to the users. For this we use similar diagrams of UML, more precisely sequence diagrams and collaboration diagrams [4; 12].

The purpose of using sequence diagrams is that it suits well when illustrating static information of knowledge bases [8], which can also be used for production systems and show strategies [9]. Collaboration diagrams on the other hand are good at illustrating dynamic phenomena, as inserted data can affect executing order [8].

The sequence diagrams are used to show the parts found in the manufactured product. These diagrams are static in the sense that it is always the same parts assembled to constitute the product.

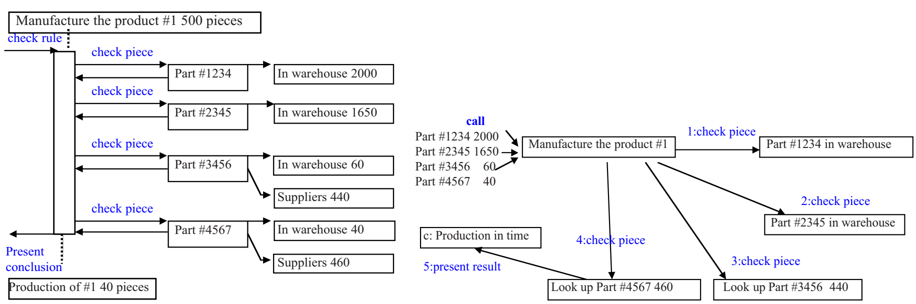

Fig. 3. Sequence diagram and collaboration diagrams illustrate the manufacturing chain

The sequence diagram and collaboration diagrams are used illustrate the manufacturing chain by showing the raw material and time aspect. The sequence diagram in Figure 5, illustrates the parts that are needed to manufacture the product #1. Moreover, the diagram shows where the parts can be found, that is either in the warehouse or at suppliers. In this case, the part #1234 and the part #2345 are in the stock already. The part #3456 and the part #4567 are not in the warehouse and need to be supplied for. The amount of pieces to produce is presented in the diagram. The order is 500 pieces, "Manufacture the product #1 500 pieces. Then to the left in the figure, the pieces found in the warehouse is presented but also how many must be purchased. Finally, the conclusion is presented, which is the amount of parts that can be produced directly from the pieces found in the warehouse.

The collaboration diagram illustrates how the manufacturing chain looks for parts to be used for manufacturing the product. If all the pieces are present, the product can be delivered in time. This is also the result presented in the diagram. This is a simplified diagram but yet it illustrates what is needed to assembly the product and what is found in the warehouses. The call to the diagram is two different parts provided by external suppliers. The square with look up pieces is to search for the pieces in the warehouse.

7 Conclusions and Further Work

In this paper, we have presented an approach using meta-agents to control the behaviour of a number of intelligent agents. The meta-agents work with the coordination of the communication that takes place in a supply chain system. The intelligent agents perform tasks between the supplier companies, searching for information about the products, price and quantity. The meta-agents combine information from the different agents to find the optimal raw material for manufacturing the product. The meta-agents can also schedule the time for production.

The current multi-agent systems search for environment characteristics while moving in the network and build meta-agents from the agents' result. Next step is to compute the combination of the result and schedule production time.

Further research has do be done on efficiency measures, and quality measures as well. Logistics should be a value adding and quality raising process. Hopefully this can be true also for Information Logistics. Our current work holds limitations that we will be addressed in the future. Some shortcomings have been identified: (*i*) problems with representation of complicated business situations, *(ii)* a tool for automating our approach with a highly interactive design.

References

1. Apelkrans, M., Braf, E.: Content Management: An Integrated Approach of Information Logistics and Knowledge Management. In: Proceedings of the Is One World conference, Las Vegas (2004)
2. Apelkrans, M., Håkansson, A.: Visual knowledge modeling of an Information Logistics Process - A case study. In: ICICKM 2005, 2nd International Conference on Intellectual Capital, Knowledge Management and Organisational Learning, Dubai, Förenta Arab Emiraten (2005)
3. Apelkrans, M., Håkansson, A.: Enterprise systems Configuration as an Information Logistics Process - A Case Study. In: Cardoso, J., et al. (eds.) Proceedings of 9th International Conference on Enterprise Information Systems, ICEIS 2007, pp. 212–220. INSTICC, Portugal (2007)

4. Booch, G., Rumbaugh, J., Jaconson, I.: The Unified Modeling Language User Guide. Addison Wesley Longman, Inc., Amsterdam (1999)
5. Chelberg, D., Welch, L., Lakshmikumar, A., Gillen, M., Zhou, Q.: Meta-Reasoning For a Distributed Agent Architecture (2000), http://zen.ece.ohiou.edu/~robocup/papers/HTML/SSST/SSST.html
6. Costantini, S.: Meta-reasoning: a survey. In: Kakas, A., Sadri, F. (eds.) Computational Logic: From Logic Programming into the Future: Special volume in honour of Bob Kowalski, Springer, Berlin (2002)
7. Frauenhofer Institute (December 10, 2006), http://www.isst.fhg.de/ englisch/download/34868_I-Log-4-Seiter-engl-2.pdf
8. Håkansson, A.: UML as an approach to Modelling Knowledge in Rule-based Systems. In: ES 2001 The Twenty-first SGES International Conference on Knowledge Based Systems and Applied Artificial Intelligence, December 10–12, 2001. Peterhouse College, Cambridge (2001)
9. Håkansson, A.: Transferring Problem Solving Strategies from the Expert to the End Users - Supporting understanding. In: Proceedings of 7th International Conference on Enterprise Information Systems, ICEIS 2005, vol. II, pp. 3–10. INSTICC, Portugal (2005)
10. Håkansson, A., Hartung, R.: Using Meta-Agents for Multi-Agents in Networks. In: Arabnia, H., et al. (eds.) Proceedings of The 2007 International Conference on Artificial Intelligence, ICAI 2007. U.S.A., vol. II, pp. 561–567. CSREA Press, USA (2007)
11. Håkansson, A., Hartung, R.: Calculating optimal decision using Meta-level agents for Multi-Agents in Networks. In: Apolloni, B., Howlett, R.J., Jain, L. (eds.) KES 2007, Part I. LNCS (LNAI), vol. 4692, pp. 180–188. Springer, Heidelberg (2007)
12. Jacobson, I., Booch, G., Rumbaugh, J.: The Unified Software Development Process. Addision Wesley, USA (1999)
13. Pechoucek, M., Stepánková, O., Marík, V., Bárta, J.: Abstract Architecture for Metareasoning in Multi-agent Systems. In: Mařík, V., Müller, J.P., Pěchouček, M. (eds.) CEEMAS 2003. LNCS (LNAI), vol. 2691, p. 84. Springer, Heidelberg (2003)
14. Reijers, H., Limam Mansar, S.: Best practices in business process redesign: An overview and qualitative evaluation of successful redesign heuristics. Omega: The International Journal of Management Science 33(4), 283–306 (2005)
15. Russell, S., Norvig, P.: Artificial Intelligence: A Modern Approach. Prentice Hall, Upper Saddle River (2003)
16. Sandkuhl, K.: Information logistics in networked Organisations Issues, Concepts and Applications. In: Cardoso, J., et al. (eds.) Proceedings of 9th International Conference on Enterprise Information Systems, ICEIS 2007, pp. 23–30. INSTICC, Portugal (2007) ISBN: 978-972-8865-90-0
17. Wooldridge, M.: An Introduction to MultiAgent Systems. John Wiley & Sons Ltd, Chichester (2002)