# 8 AGENT-BASED ARCHITECTURE FOR INFORMATION HANDLING IN AUTOMATION SYSTEMS

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*This paper studies issues concerning the application of cooperative information agents to information handling in automation systems. The suggested approach utilizes agent-based layer as an extension to ordinary automation system, thus offering new functions without the need of replacing the existing automation system. The proposed architecture uses agent-based cooperation methods to enable flexible integration of heterogeneous and distributed data sources and functional or spatial hierarchical division for data abstraction and information filtering. In this case, information agents use BDI-model based manager and data handling modules for information processing. The approach is described with real-life inspired test scenario.*

## 1. INTRODUCTION

Within the rise of the total complexity and the vast amount of acquired information in the automation systems there is a growing need for more powerful design methodologies and techniques. These methodologies should enable easier searching, combination and filtering of information to support end users decision-making. This paper discusses the potential match between properties that information agents provide and generic requirements in automation domain. This paper presents an agent-based architecture to take an advance of information agent technology for automation information handling problems. Agent-based information handling in automation is new research area as previously the application of agents has been focused to control functions.

This paper is outlined as follows: In Chapter 2 information solutions in automation system are represented together with a short review of information agents in other application domains. The suggested architecture is presented in Chapter 3 and the internal design is discussed in Chapter 4. The test scenario is represented in Chapter 5. Finally the conclusions and open questions are discussed in Chapter 6.

## 2. AUTOMATION AND INFORMATION AGENTS

First of all, the trend in information systems in automation is towards generic solutions and open architectures, i.e., the ability to combine different vendors' solutions is preferred (Tommila et al., 2001). Secondly, generic distributed information systems have evolved strongly and they have a number of properties that are also desired in the automation domain. Such properties are maintainability, openness, reliability, scalability, and easy connection between different resources (Tanenbaum and Steen, 2002). These issues motivate the further development of information systems in automation context.

### 2.1 Information Systems in Automation

The emphasis in information processing solutions in automation has traditionally been on reliability and solutions have typically been stand-alone (Tommila et al., 2001). In systems level, present day solutions are mainly based on OPC standard (OPC, 2004). This standard provides reliable real-time data access for individual variables and their continually changing numerical values. Also mechanisms for alarm events and access for history data is offered. In the instrumentation level the latest fieldbus standards provide all-digital two-way communication between the devices with modest support of control application design and implementation. Currently, the trend in the instrumentation level is towards more intelligent devices, which produce more and more diagnostic and monitoring information. Unfortunately this useful information is usually provided in vendor specific format.

In addition, spatially distributed instrumentation produce a huge amount of pure numerical data, which has to be processed in real-time, as it is available only in certain time window. Within information handling in automation the emphasis has traditionally been on enabling raw data exchange between distributed resources, while the semantic meaning of data has got little attention.

### 2.2 Agent-Based Information Systems

Efficient operation in knowledge intensive business needs right information, in the right place, and in right time. As the capacity of data storage and communication bandwidth are getting cheaper the information overload for the human operator has clearly emerged (Knowles, 1999). Agents as a design methodology and implementation tool might provide means to handle this (Ferber, 1999; Jennings, 2000; Luck, 2003, 2004; Tropos 2004). Recently, multi-agent technology has matured up to an industrial standard (FIPA, 2004). Some systematic engineering and documentation methods are also proposed (Luck, 2004, Tropos, 2004).

Lately interest has been in information agents communicating with meaningful messages based on shared ontology. Generally an information agent is a computational software entity that gathers and integrates information from heterogeneous and distributed data sources. One potential way to program these agents is to use BDI-model (Belief-Desire-Intention, see Rao and Georgeff, 1995; Ferber, 1999), and define information handling tasks as goals that agents try to achieve with searching, filtering and combining information. Furthermore, a variety of brokering techniques have been developed to match service requesters and service providers (Klush et al., 2003), including the use of semantics (Nodine el al., 2003).

### 2.3 Possibilities of Information Agents in Automation

In the automation domain there is a clear need for systematic design method for information handling in an environment that is distributed and dynamically changing by nature. On the one hand, agent-based architectures for automation control functions have been proposed by a number of researchers (Cockburn and Jennings, 1995; Parunak, 1999, Marik et al., 2002; Seilonen et al., 2002), and an industrial demonstration has also been presented (Jennings and Bussmann, 2003). Most of these architectures locate agents to a separate layer on the top of the physical automation system. On the other hand, applications of information agents in other application domains have number of aspects in common with automation applications, e.g., searching information from heterogeneous data sources.

Furthermore, using ontologies to define semantic meaning of messages has been studied, e.g., (OWL, 2004), and it is argued that these technologies could be useful in manufacturing applications (Obitko and Marik, 2003). In automation applications it could be valuable to apply an approach, where planning and execution are interleaved, as this is argued to support adaptation to changing environmental situations (desJardins el al., 1999).

Although a large number of useful technologies for effective information processing have been proposed, no combining architecture has been presented yet. Therefore, this paper introduces an architecture that integrates various above mentioned useful technologies.

## 3. AGENT-BASED INFORMATION SYSTEM ARCHITECTURE IN AUTOMATION

The purpose of information agents in the context of automation systems is to provide an additional intelligent and active information access layer, which will enable more easy and efficient utilization of information for human users. The information agents are intelligent in the sense that they handle information access goals. When an information access goal needs to be fulfilled the information agents will cooperatively find a way to provide that information if possible. The activeness of the information agents means that they can take initiative in information access. They can start cooperative information access operations themselves, if they just are aware of users interests.

To be able to use ordinary agent software development tools our information agents were situated to a separate layer on top of existing automation hardware and software, this is illustrated in Figure 1. This design follows our previous work with controlling agents (Seilonen et al., 2003).

### 3.1 Roles of Information Agents

The information agents form a cooperative agent society, where each agent has a certain role. We have defined these roles in the case of an automation application. Currently, this architecture includes agents operating in the following roles: *Client-*, *Information-*, *Process-*, and *Wrapper Agent* (e.g., see Figure 1). There the *Client Agent* provides human user an interface, and translates human understandable queries to agent communication language. *Information Agent* decomposes information queries to subqueries. *Process Agent* is responsible of certain spatially or functionally divided area of the total manufacturing process and *Process Agents* are arranged in hierarchically form to support information abstraction. *Wrapper Agent* is used to access the information stored in legacy information systems.

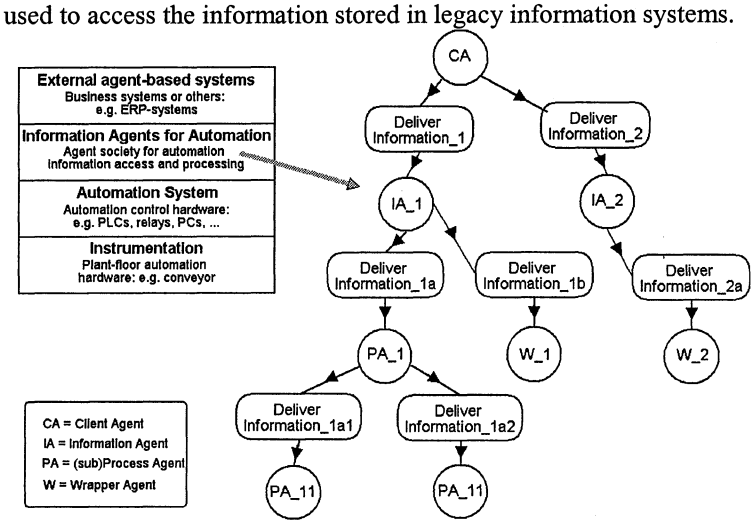


Figure 1 – an example of hierarchical setup of information agents

In our FIPA standard based approach agents register their services to the Directory Facilitator (DF) (FIPA, 2004). Although, agents register mainly that they are providing information, interest of certain information may be register also. Such information could be alarms or operation mode changes.

### 3.2 Functions of Information Agents

Potential functions for information agents in automation context include: diverse monitoring and diagnostic functions, advise the operator in the selection of operation mode, filtering relevant alarms from enormous number of alarms based on operational states, etc. Generally, functions that are decentralized by nature and benefit from agent cooperation are suitable for information agents. Especially, information agents could monitor actively in the device level and share information about emerging problems.

## 4. DISTRIBUTED INFORMATION PROCESSING BASED ON DOMAIN ONTOLOGY

The information agents need an internal design, which will give them the particular capabilities they need in their goal-oriented and cooperative information access operations. The BDI agent model is very suitable as a basic architecture for agents with goal-oriented operation. In addition to this, the information agents utilize FIPA interaction protocols as cooperation mechanisms and ontologies as data modeling technique. In this architecture, the domain ontology is the foundation for defining various models describing the process for the agents. The design of information agents should also enable the use of other information processing methods, such as principal component analysis or statistical methods.

### 4.1 BDI-model based Information Processing

The manager module controls the planning and execution of individual information access and processing tasks inside one agent. When information delivery goal is received the manager partitions it to a number of subgoals that match up to specific atomic operations. The execution of these operations is then conducted by individually information processing modules, illustrated in Figure 2.

First of all, the manager operation depends on the used interaction protocol, which specifies how and when to respond to the information delivery goal. Then the message content specifies what information processing modules are needed to fulfill the information delivery goal. If there is no internal module that can fulfill certain subgoal the manager tries to find out if some other agent is able to deliver this partial information. In this architecture the role of the manager is to decide which modules are used for information processing but not how.

### 4.2 Modules for Information Content Processing

The actual information processing is performed by modules, which are specialized to certain functions (see Figure 2). With information input modules these operations correspond to units of information read from particular information source (database, file, or conversation with other agents). Information processing module provides filtering, reasoning, and computational operations. Information output modules are used to distribute the processed information to other agents with conversations. Data exchange between different modules is based on domain specific ontology.

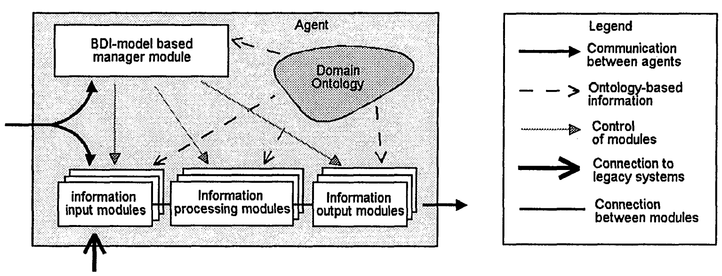


Figure 2 - Internal design of BDI-model based information agents

Using separated modules for different information processing functionalities is argued to enable easy system updates in the future. New modules with new features may be constructed and added to the existing ones without a need to program the operation of the manager entirely again.

### 4.3 Engineering Viewpoint

General agent platform services (communication and BDI-model agents) may be packed up with information agent services (matchmaking, and information delivery ontology) to form a basis for an engineer to build up an agent application. On top of that, at least conceptually, there is a layer providing configurable tools for automation information processing. The configuration files describing the particular application are left to the uppermost and distinct layer. In engineering viewpoint the idea is to provide user the possibility to program the operation of these agents with intuitive concepts and leave the description of the physical configuration of the production environment to a separated process models.

# 5. APPLICATION OF INFORMATION AGENTS IN PAPER MAKING

Our test case consists of preliminary implementation of information agents, which have connection to legacy information systems containing real production data. Generally the properties of pulp and paper are difficult to measure as the instrumentation that is used to measure important process quantities (e.g., pH, consistency, brightness) is subject to fouling and drifting (Leiviskä, 1999). Because the direct detection of malfunctions is problematic, most important measurements are crosschecked with physically doubled instrumentation and laboratory measurements may be used to verify the long-term stability.

## 5.1 Wrappers for Fusion of Measurement Information

The goal of our first test scenario was to produce integrated information about the operational condition of physical instrumentation to process operator. Initially this information was available in different user interfaces, and it was stored in three separate data sources using different data formats. In this scenario the *Information Agent* uses domain ontology to find out the different information types and DF to search responsible *Wrapper Agent* for each of these information types. As the *Wrapper Agents* are programmed to answer information queries in common presentation format, specified in the domain ontology, the fusion of information is straightforward. Sequence diagram for this scenario is shown in Figure 3.

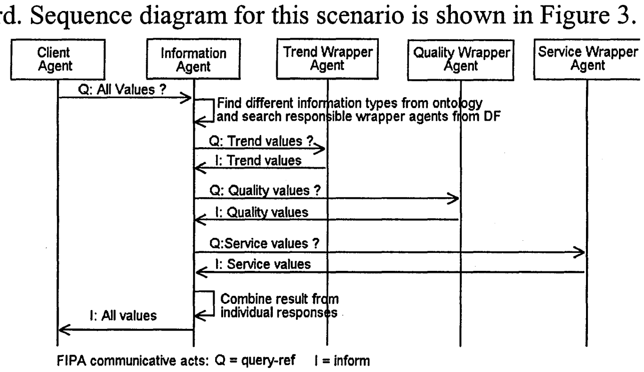


Figure 3 - Sequence diagram for fusion function

In the first test scenario the selection of FIPA query interaction protocol is reasonable as the requested data is available immediately in the data sources. In addition, the FIPA standard suggests the use of query-ref when the initiator agent wants some information that another agent knows. (FIPA, 2004)

### 5.2 Wrappers for Active Condition Monitoring

The second test scenario concerns the validation of online measurements. Uncertain on-line measurements are automatically compared by the agents to the exact laboratory measurements. As these laboratory measurements are available in certain time intervals, it was decided to use *Wrapper Agents* actively supervise the appearance of new measurements. When new laboratory measurement is available in legacy information system the *Wrapper* informs this to *Information Agent,* which may then use case-specific algorithm to find out if device is malfunctioning.

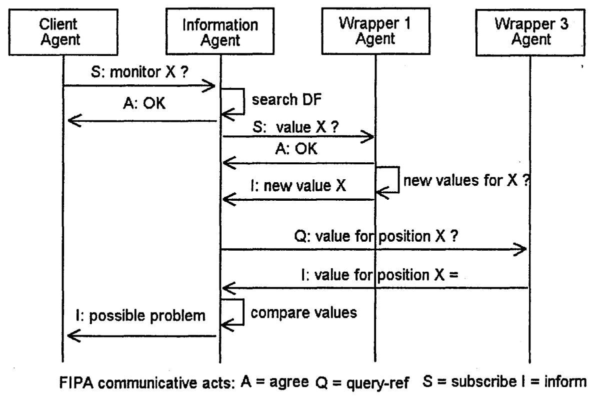


Figure 4 - Sequence diagram of monitoring function

In this scenario the use of FIPA subscription interaction protocol is justified by the fact that process operator is interested only in changes in monitoring status. These changes are possible only in times when new laboratory measurements are fed to the system. Furthermore, the FIPA standard suggests the use of subscription protocol when the initiator agent wants another agent to notify continuously about changes in the specified information. (FIPA, 2004)

## 6. CONCLUSIONS

In this paper an agent-based architecture for automation information handling is presented. The motivation for this architecture is the possible match between features that information agent technology tools provide and the needs of information processing in the automation context. This architecture gives the possibility to use systematic agent-oriented software engineering methods to construct automation information functions, and further realize the designs with latest agent platform implementations. Furthermore, our first two implemented test scenarios are targeted to help process operators to monitor the functionality of process devices.

In the future, the presented information agent architecture may be used to combine agents for automatic control and agents for information processing. Future research focuses on designing more functions based on this architecture and testing these by implementing them. Furthermore, using formal methods to describe the automation domain ontology for reasoning purposes and for the interaction between the agents is under further development.

## 7. REFERENCES


1. Cockburn D and Jennings NR. "ARCHON: A distributed artificial intelligence system for industrial applications". In Foundations of Distributed Artificial Intelligence, O'Hare GMP, Jennings NR, ed.: Wiley & Sons, 1995.
2. desJardins ME, Durfee HD, Ortiz CL Jr., Wolverton MJ, "A Survey of Research in Distributed, Continual Planning". AI Magazine, 4, 13-- 22, 1999.
3. Ferber J. "Multi-agent systems: An introduction to distributed artificial intelligence". Addison-Wesley, 1999.
4. FIPA. The Foundation for Intelligent Physical Agents, http://www.fipa.org, 2004.
5. Jennings NR. "On agent-based software engineering". Artificial Intelligence 117, 277–296, 2000.
6. Jennings NR and Bussmann S. "Agent-based Control Systems". IEEE Control Systems Magazine, 2003.
7. Knowles C. "Just-in-time information," Proceedings of the Second International Conference on the Practical Application of Knowledge Management, 1999.
8. Klush M, Omicini A, Ossowski S, Laamanen H. "Cooperative Information Agents VII", Lecture Notes on Artificial Intelligence 2782, Springer, 2003.
9. Leiviskä K. "Process Control", Vol 14 of the Papermaking Science and Technology Series, TAPPI, ISBN: 952-5216-14-4, 1999.
10. Luck M, McBurney P, Preist C. "Agent Technology: Enabling Next Generation Computing". AgentLink, ISBN 0854 327886, 2003.
11. Luck M, Ashri R, D'Inverno M. "Agent-Based Software Development". Artech House Publishers, ISBN: 1580536050, 2004.
12. Marík V, Fletcher M, Pechoucek M. "Holons & Agents: Recent Developments and Mutual Impacts". In Multi-Agent Systems and Applications II, Marik V, Stepankova O, Krautwurmova H, Luck M, ed. Springer-Verlag, Germany, pp. 323-335, 2002.
13. Nodine M, Ngu AHH, Cassandra A, Bohrer WG. "Scalable Semantic Brokering over Dynamic Heterogeneous Data Sources in InfoSleuth™", IEEE Transactions on Knowledge and Data Engineering, Vol. 15, No. 5, 2003.
14. Obitko M and Marík V. "Adding OWL Semantics to Ontologies", Holonic and Multi-Agent Systems for Manufacturing (HoloMAS), pp. 189-200, 2003.
15. OPC. OPC Foundation, http://www.opcfoundation.org/, 2004.
16. OWL. Web Ontology Language, http://www.w3.org/TR/owl-ref/, 2004.
17. Parunak DH. "Industrial and practical applications of DAI". In Multiagent systems, Weiss G ed. Cambridge, MA, USA, pp. 377-421, 1999.
18. Rao AS and Georgeff MP. "BDI agents: From theory to practice". Tech. Rep. 56, Australian Artificial Intelligence Institute, Melbourne, Australia, 1995.
19. Seilonen I, Pirttioja T, Appelqvist P. "Agent Technology and Process Automation". 10th Finnish Artificial Intelligence Conference (STeP 2002), Oulu, Finland, December 16-17, 2002.
20. Seilonen I, Pirttioja T, Appelqvist P, Halme A, Koskinen K. "Cooperating Subprocess Agents in Process Automation". 1st International Conference on Applications of Holonic and Multi-Agent Systems (HoloMAS 2003), Prague, Czech Republic, September 1-3, 2003.
21. Tanenbaum AS and Steen MV. "Distributed Systems: Principles and Paradigms". Prentice Hall, ISBN: 0-13-088893-1, 2002.
22. Tommila T, Ventä O, Koskinen K. "Next generation industrial automation – needs and opportunities". Automation Technology Review 2001, VTT Automation, 34-41, 2001.
23. Tropos. Agent software development methodology, http://www.troposproject.org/, 2004.