

Agent-based intelligent system development for decision support in chemical process industry

Ying Gao, Antonis C. Kokossis*
Chemical Process Engineering, University of Surrey
Guildford, Surrey, GU2 7XH UK

Abstract

This paper experiments with an agent-based system designed to support decisions in chemical process industry. Chemical engineering technology, artificial intelligent and information technology are integrated to automate decisions on-line. A multi-agent system is employed to coordinate tasks and information stored in heterogeneous resources. The system architecture is first discussed in this paper. The implementation of the system provides an environment to coordinate manufacturing and integrate rules, optimization and simulation models.

Keywords: Multi-agent system, artificial intelligence, information integration, coordinate manufacturing and decision support.

1. Introduction

Data and information resources are important assets of the chemical process industry. Their effective management and sharing are vital to maintain sustainable operations. Available assets include several software applications, models, reports (text, design results, software solutions etc) that are largely unstructured making it difficult for search, management procedures and computer environments to register and support management. The development of agent-based tools enables flexible infrastructures that support integration, manufacturing management, information sharing, and decision-support. In contrast to traditional software programs, software agents facilitate collaboration and integration of software as well as access to in-house resources (Bradshaw, et al., 1997). Agent-based systems have capabilities to function in networked distributed environment and cope with system changes (Nwana, 1996). Agents can further incorporate legacy programs by building wrappers around the program that manage interactions with other systems (Genesereth and Ketchpel, 1994, p. 48) and require only minor modification as programs change or replaced.

*To whom the correspondence should be addressed: a.kokossis@surrey.ac.uk

In this paper, we explain the prototype of an agent-based system with a focus on on-line operations and negotiations. The paper is organized as follows. Its first section, introduces basic concept. The system architecture is described next with an emphasis on the decision-support tools to use in the chemical process industry. Implementation issues are last discussed with an example of an operational scenario.

2. Multi-agent system and agent communication

2.1 Multi-agent system

Multi-agent systems (MAS) have their origin in distributed artificial intelligence and object-oriented distributed systems. An agent is a computational process that implements the autonomous, communicating functionality of an application (FIPA00023, 2000). The intelligent agents have capabilities to acquire information from its environment and make decisions. Agents are relatively independent pieces of software interacting with each other through a message-based communication. Two or more agents acting together form a multi-agent system. Unlike those stand-alone agents, agents in a multi-agent system collaborate with each other to achieve common goals. These agents share information, knowledge, and tasks among themselves. Cooperation and coordination between agents is the most important feature of a multi-agent system.

Major advantages in utilizing agent-based techniques are that:

- Multi-agent systems have capabilities to incorporate legacy programs using wrappers that one could build around them so that the legacy programs can be accessed and exploited. Systems can be incorporated into wider cooperating agent systems and rewriting of application programs can be avoided.
- Multi-agent system can provide efficient solutions when information sources and expertise is distributed in the chemical manufacturing process.
- Application of agent-based systems help to enhance system performance in the aspects of computational efficiency, reliability, extensibility, maintainability, flexibility and reusability (Sycara, 1998). System development, integration and maintenance are easier and less costly. It is easy to add new agents into the multi-agent system, and the modification can be done without much change in the system structure.

2.2 Agent communication

Cooperation and coordination of agents in a multi-agent system requires that the agents be able to understand each other and communicate effectively. The infrastructure that supports the agent cooperation includes the following key components:

- a common agent communication language (ACL), and
- a shared ontology (Wooldridge, 2002).

Agents typically communicate by exchanging messages represented in a standard format and using a standard agent communication language (ACL). A number of ACLs have been proposed, in which Knowledge Query and Manipulation Language (KQML) (Finin, et al., 1997, p. 291) and FIPA's agent communication language (FIPA ACL) (FIPA00023, 2000) are used most frequently.

If two agents are to communicate about a specific domain, then it is necessary for them to agree on the terminology that they use to describe the domain. In the terminology of the agent community, agents must share a common ontology. Ontology is defined as specification schemes for describing concepts and their relationships in a domain (Gruber, 1993, p. 199). Once interacting agents have committed to a common ontology, it is expected that they will use this ontology to interpret communication interactions, thereby leading to mutual understanding and predictable behaviors. With a common communication language, and a shared ontology, agents can communicate with each other in the same manner, in the same syntax, and with the same understanding of the domain.

3. Agent-based information system architecture for decision support in chemical process industry

Figure 1 presents the system architecture. The integrated components include process simulation, rules that comprise a decision support system, and black box regression tools in the form of artificial intelligent components and neural network (ANNs) for process analysis, data processing, process monitoring and diagnosis, process performance prediction and operation suggestion.

The system comprises a knowledge base with access to software agents, and a user interface. A system knowledge base comprises process models, heuristics, as well as process data. Process models may include models for process simulation, optimization, scheduling, forecasting, and manufacturing planning and can be developed utilizing different computing languages and software. Forecasting applies to the history data and real-time data of plant operation and management. Heuristic rules provide for on-line decisions that may or may not use optimization models. Information on expert knowledge and technical resources related to the chemical manufacturing process are also provided in the knowledge base.

The agents can be specialized around specific expertise and tasks to assemble and process relevant information and knowledge utilizing the available resources in the knowledge base. They could also negotiate and cooperate with each other to achieve timely decisions in dealing with different operational scenarios. Scenarios can involve negotiations with trading points and other agents.

Agents are organized in a layered, distributed system, which comprises *user agents*, a *coordinator* and *task agents*. User agents process jobs triggered by users and managed by the coordinator that ushers jobs and regulates communication. The task agents are

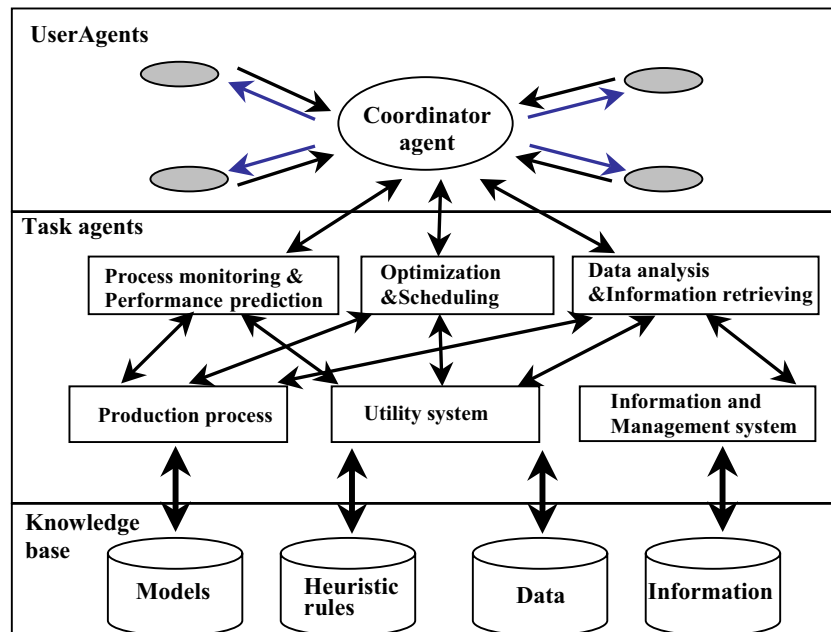


Figure 1. Agent-based information system architecture

assigned to different processes that monitor performance, forecast trends, apply optimization, support scheduling and planning decisions and develop scenarios for negotiation. Monitoring agents review performance and may release warnings about abnormal operations. Forecasting agents develop trends applying artificial neural network. Data management agents collect data, and apply mining and clustering. A separate set of agents is devoted to analyze text from documents following h-techsight technology (Banares et al., 2003). These agents employ Natural Language Processing analysis to retrieve text from reports, populate ontologies with relevant resources, correlate resources and update ontologies, and apply background search.

The system infrastructure supports communication between previously established application software and programs for process simulation, optimization, scheduling and forecasting. Agents can run on the same or different computers, and information sources can be stored in distributed locations. This enables applications in networks of CPU's as these exist in industrial R&D environments. The cooperation and coordination is exemplified in negotiation examples of open markets, as this can be the case of utility networks that can trade steam and power in changeable environments. Utility systems have to compete with main grids, mini-grids, and local suppliers and service regular (process operations) and unplanned customers, as they become available during peak demand periods.

4. System implementation

JADE (Java Agent Development Framework) is used as a standard to develop the different agents described above. A user interface is constructed to account for a functional access to tasks, services and data. The agents communicate in FIPA, use ACL for security and control in the communication, and employ machine interpretable ontologies in RDFS. With the common communication language and shared ontologies, agents can launch experiments in negotiation, and integrate decision stages with models, rules and operational data.

A simple illustration case is next presented to demonstrate the application of agents on a process operation case.

Benzene-toluene separation process is selected as a process with an objective to monitor process operation condition and adjust process operation parameters in the case of abnormal situation. Agents are used to:

- (i) monitor operational data and compare data with acceptable profiles
- (ii) calculate the abnormal error and optimize the maintenance schedule
- (iii) warn and alarm about operational failures and under-performance
- (iv) communicate with users for authorization and decisions
- (v) forecast operational changes and economic impact

Figure 2 illustrates the user interface of the agent-based system for process performance prediction. A simple ontology is developed to model the basic knowledge behind the process and allocate the different agents and models employed in the experiment.

- Agents in (i) apply a rule based system that calculates deviations from design profiles. Flags for acceptable or unacceptable performance are set by the agent to the user.
- Agents in (ii) and (v) apply models that make use of artificial neural networks trained from history data of 30,000 points that represent operation of a past year. ANN's apply back-propagation to tune parameters.

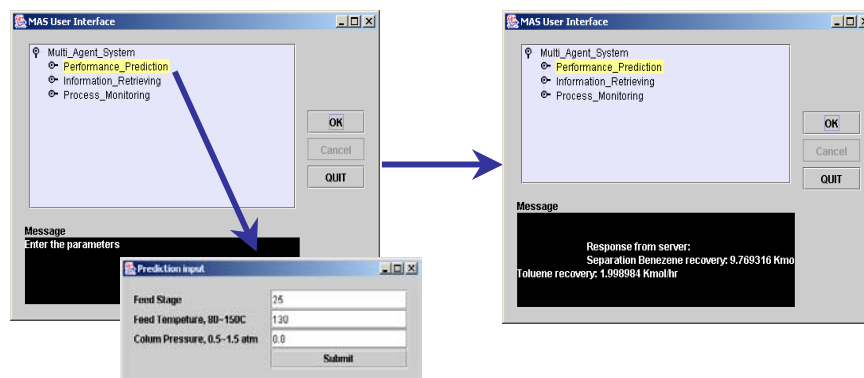


Figure 2. User interface for process performance prediction

- Agents in (iii) apply simple rules with the flags noted earlier.
- Agents in (iv) launch communication windows such as the ones shown in Figure 2.

Forecasting models are programmed in C and wrapped by JAVA Native Interface (JNI). The coordination of monitoring agent and prediction agents operate at regular time intervals.

5. Conclusion and future work

In this paper we presented an agent-based system capable of supporting information integration and decision-making for the chemical process industries. The system architecture is discussed first. Knowledge management is applied with the use of ontologies to integrate regression, simulation and optimization models, heuristic rules, and data management tools. The Java Agent Development Framework (JADE) has been deployed as the basis. With a common communication language and shared ontologies, agents cooperate to exchange and share information, and achieve timely decisions in dealing with various enterprise scenarios.

The system has also been tested in a variety of negotiation problems that involve utility networks and trade energy and power. Agents take up negotiations, trigger optimization studies and determine prices dynamically. The paper illustrates a maintenance problem that requires the monitoring of data, comparisons with design solutions, and optimization. Agents manage information on-line, process tasks and communicate recommendations to users who authorize decisions. The work illustrates the potential of the technology to change the shape of process engineering practices and upgrade the quality of the environments currently in use.

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