ProMAIS: A MULTI-AGENT MODEL FOR PRODUCTION INFORMATION SYSTEMS

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Abstract: In the age of information proliferation and communication advances, Cooperative Information System (CIS) technology becomes a vital factor for production system design in every modern enterprise. In fact, current production system must hold to new strategic, economic and organizational structures in order to face new challenges. Consequently, intelligent software based on agent technology emerges to improve system design on the one hand, and to increase production profitability and enterprise competitive position on the other hand. This paper starts with an analytical description of logical and physical flows dealt with manufacturing, then proposes a Production Multi-Agent Information System (ProMAIS). ProMAIS is a collection of stationary and intelligent agent-agencies with specialized expertises, interacting to carry out the shared objectives: cost-effective production in promised delay and adaptability to the changes. In order to bring ProMAIS's dynamic aspect out, interaction protocols are specially zoomed out by cooperation, negotiation and Contract Net protocols.

1 INTRODUCTION

The use of the Information System (IS) technology today has already imbedded into every modern enterprise's core as a result of the quantity of information and the need of sharing them.

Recent developments, driven by the proliferation of parallel architecture, the advances in wide area net-working and the Internet democratization, have made the information systems parts of increasingly complex systems. That's how the classic IS are becoming hard to generate necessitating to break them up into sub-systems and distribute them. This results in the birth of the Cooperative Information Systems (CIS) technology. The CIS aim at continued cooperativity among user groups through componentized networks of information systems.

One of the most important classes of IS are production systems. Such system consists in an important domain from strategic, economic and organizational points of view. A number of new concepts of such systems has been proposed and developed in the past few years, e.g., Virtual Organizations, Virtual Enterprise, Supply Chain Management and Electronic Commerce, etc. These concepts are similar or overlapping.

Currently, the world is undergoing a Hi-Tech industrial revolution with information technology as its main feature. The production systems will be characterized by intensively concurrent engineering based on information technologies such as digitalization, computer network, artificial intelligence (Qiao et *al*, 1999).

To compete effectively in today's markets, manufacturers must be moving towards an open and

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distributed architecture. Increasingly, traditional centralized and sequential manufacturing or production system decisions are being found insufficiently flexible to respond to changing production styles and highly dynamic variations in production requirements.

The intelligent software agents technology provides a natural way to overcome such problems. In sharp contrast to traditional software programs, software agents are programs that help people to solve problems by collaborating with other software agents and other resources in the network. That's how, the use of the agent-oriented approach is imposed in contrast to the object-oriented approach.

Recently, agent technology has been considered as an important approach for developing intelligent manufacturing and production systems. Agents help to capture individual interests, local decision-making using incomplete information, autonomy, responsiveness, robustness and modular, distributed, reconfigurable organizational structures.

A Multi-Agent System (MAS), as a society of autonomous agents, is an inherently open and distributed system. It is formed by a group of agents combined with each other through a network to cooperatively solve a common problem. The system's inter-agent communication capability provides the essential means for agent collaboration that aids interoperability of the system.

There is a multifold advantage in using an agent-based approach for manufacturing and production systems. First, information for production system is stored and processed in a distributed manner in contrast to that stored in one large program. Second, the agent-based approach makes the incremental improvement of the production system possible through learning and cooperation between agents. Third, it provides a promising method for enterprise integration (Qiao et *al* 1999).

In this paper we present our research efforts and experiences in analysing the information (logical) and physical flows between the various divisions of the enterprise, modeling an intra-organization cooperative information system based on decomposition into recursive agents, developing a MAS architecture named Production Multi-Agent Information Systems (ProMAIS). ProMAIS is an ongoing project. It is an organizational structure which draws descriptions of flows between actors in the production systems. It allows the actors involved to communicate with each other, to conserve the autonomy of every one in making local decision, to guarantee the adaptability and ability to quickly respond to the changes and the new conditions of markets and to react quickly to unexpected risks.

The remainder of this paper is structured as follows: section 2 reviews research literature, section 3 presents ProMAIS the Multi-Agent model for Production Information Systems, section 4 presents a prototype implementation, section 5 gives concluding remarks and perspectives.

2 RESEARCH LITERATURE OF AGENT TECHNOLOGY IN THE INDUSTRY

Recently, agent technology has been considered as an important approach for developing industrial distributed systems. A number of researchers have attempted to play agent technology to industrial enterprise integration. In this section, we briefly review some interesting projects in this domain such as MetaMorph II (Shen et *al*, 1998) and an Agent-Based Intelligent Manufacturing System for the 21st Century (Qiao et *al*, 1999).

At the university of Calgary, the MetaMorph II project start at the beginning of 1997. The aim of this project was to integrate the manufacturing enterprise's activities such as design, marketing, planning, scheduling, execution and product distribution, with those of its suppliers, customers and partners into an open distributed intelligent environment. To do this, the researchers propose an Agent-Based Manufacturing Enterprise Infrastructure (ABMEI) combining and extending the architecture used in previous projects MetaMorph I (Maturana et *al*, 1996), ABCDE (Balasubramanian et *al*, 1996) and DIDE (Shen et *al*, 1996). In this Infrastructure, the system is primarily organized at the highest level through sub-system mediators which are connected via the Internet/Intranet. Each sub-system is connected to the system through a special mediator. Each manufacturing enterprise must have at least one Enterprise Mediator. It can be considered as the administration center of the enterprise. All other mediators should register with it.

Qiao shows in (Qiao et *al*, 1999) that the intelligent manufacturing system is a solution of the problems of the 21st century manufacturing industry. In order to establish an Agent-Based Manufacturing System, they propose an intelligent object called Manufacturing Agent (MA). According to the general structure of the manufacturing enterprise, they propose the Agent-Based Manufacturing System architecture, in which the whole operation logic of a manufacturing enterprise is divided into four parts: central part, management, planning and production. Each part consists of a group of MAs.

All the MAs are connected to the distributed enterprise network or Intranet. This MA network is heterarchical in nature.

3 PRODUCTION MULTI-AGENT INFORMATION SYSTEMS (ProMAIS)

In order to present our ProMAIS model, we must first exhibit how to 'agentify' the IS.

3.1 Information Systems as MASs

The definition of Hayes-Roth (Hayes-Roth, 1995) advocates the most important features of an agent. Therefore, intelligent agents continuously perform three functions. First, the ability of perception of dynamic conditions in the environment. Second, the capability of action to affect conditions in the environment. Finally, the ability of reasoning to interpret perceptions, solve problems, draw inferences, and determine actions. Autonomous agents have the opportunity and ability to make decisions of their own.

Nevertheless, in the case of an agentified IS, the perception of dynamic conditions in the environment refers to different kinds of incoming messages that perform a communication event (such as receiving an acknowledgement of a sales order or receiving a request for a sales quotation) and environment events (such as receiving a payment). The action to affect conditions in the environment refers to communication acts of the agentified IS (such as acknowledging a sales order) and to physical acts (such as making a payment or delivering goods). Finally, the reasoning to interpret perceptions, solve problems, draw inferences and determine actions refers to the computational inference of correct answers to queries, the proper processing of incoming messages and the determination of proper actions (such as checking all sales orders of a customer whose credibility is in question or using an alert when the fulfilment of a commitment is overdue).

Therefore, an IS may be explicitly designed as an agent (Wagner, 2000) by treating its information items as its beliefs or knowledge, adding further mental components like perceptions (as incoming messages) memory and commitments and providing support for agent-to-agent communication on the basis of a standard Agent Communication Language (ACL) (Labrou et *al*, 1999).

3.2 System design

The actors of an enterprise are collectively responsible for carrying out a common objective. The common objective consists in making cheaper and more cost-effective products. However, 'cost-effective' means the production with the best quality, in the promised delay and with a much lower price. The entities are very interdependent and interact to respond to the same objective and to assure the improvement of its performance. Each entity operates under a number of constraints and objectives and is responsible for its process and its production. Hence, the performance of each entity depends on the performance of the others and of their good cooperation. Thus, each entity has its own mission to contribute to the global goal of the net and it is connected to other entities defined with hard collabration relationship. Modeling such entities with agent technologies provides a natural way to cover such features. Our proposed model ProMAIS is a way of modeling such entities.

ProMAIS is based on reflexivity and heterogeneity. The reflexivity implies that an agent is itself a MAS and inversely. Agents should have capability of controling their interaction with the external environment and their internal decision. ProMAIS is composed of a number of agents forming a MAS (see figure 1). The diversity of agents implies the heterogeneity of the architecture of knowldge representation and exchanged messages.

Thus, our approach involves a number of agents continually in interaction. ProMAIS is built on the eco-resolution model proposed by Ferber and Jacopin (Ferber & Jacopin, 1990) and enriched by Ghedira (Ghedira, 1994). It's consist in a MAS in which each agent has a local memory that consists of the static and the dynamic knowledge, the acquaintance (the agents that it know and communicate with) and a mailbox in which it receives different kinds of messages, that it stores and treats one by one according to their priority degree. In addition, each agent has a behaviour based on satisfaction (see figure 2).

```
While (MailBox not empty)
 Withdraw_And_Treat_First_Message;
 If Satisfy
    Satisfaction_behaviour;
 Else
    Unsatisfaction_Behaviour;
EndIf
```

Figure 2: The general agent behaviour.

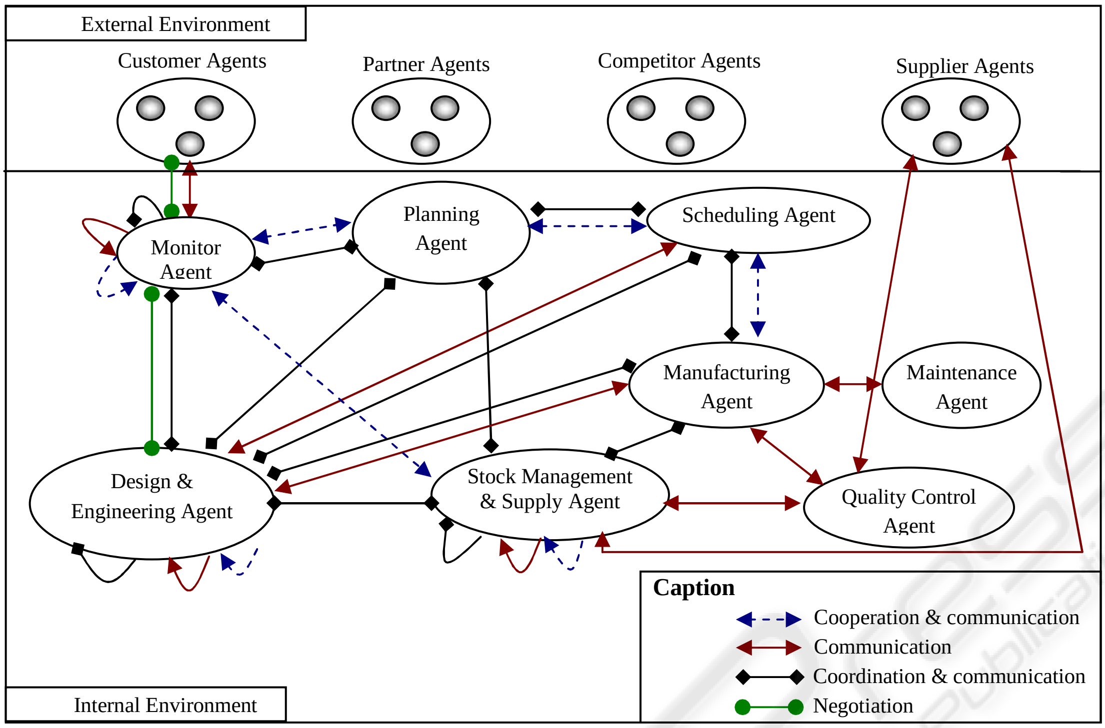

Figure 1: Organizational structure and Interaction model of ProMAIS.

In the ProMAIS organizational structure, we can distinguish two environments: internal and external one. The external environment includes all kinds of external actors to the enterprise such as *Partner* agents, *Supplier* agents, *Customer* agents and *Competitor* agents. As part of our study, we take an interest in *Customer* and *Supplier* agents ones. The internal environment contains all entities of a manufacturing enterprise. In our proposed model, agents having a MAS architecture have a common mailbox beside their individual ones. This common mailbox belongs to a *Messenger* agent. This agent has the role of communicating the received message to the appropriete agent. Furthermore, it constitues the interface between the local MAS agents and the other agents in the global model.

The *Monitor*, the *Design & Engeneering* and the *Stock Management & Procurement* agents have a MAS architecture in ProMAIS. The organizational structure of each one is shown in figures 3, 4 and 5 respectivly.

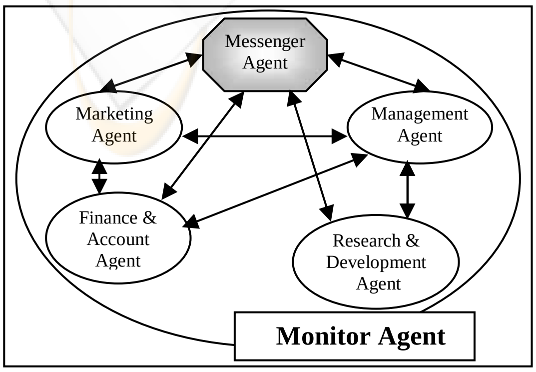

Figure 3: Organizational structure of Monitor Agent.

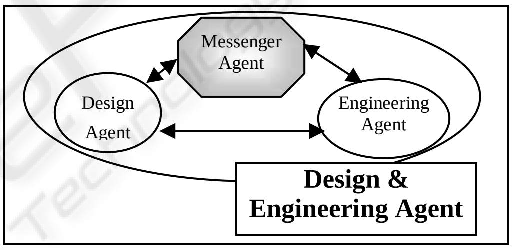

Figure 4: Organizational structure of Design & Engineering Agent.

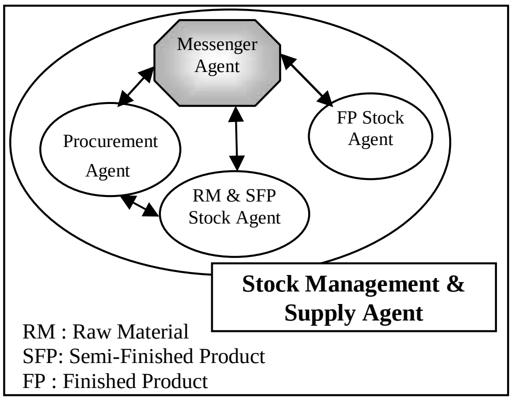

Figure 5: Organizational structure of Stock Mangement & Procurement Agent.

3.3 MAS Dynamic aspect

3.3.1 Communication protocol

A communication act consists of an information transmission from a sender to a receiver. This information is encoded into an ACL (Agent Communication Language), and it is decoded by the receiver (Labrou et *al*, 1999).

Our MAS communication protocol is based on an intentional point-to-point mode (between two agents), a broadcast mode (one to all agents), or a multicast mode (to a selected group of agents). It uses the folowing two message primitives:

SendMsg (Sender, Receiver, “Message”).

GetMsgs (MailBox) to extract all current messages from the agent mailbox and reconstitue the message list according to the priority degree of each message and the agent internal believes.

In order to capture more semantics of MAS dynamic aspects, it is necessary to make an ontological distinction between the simple communication, the coordination, the cooperation and the negotiation (see figure 1).

3.3.2 Cooperation protocol

Agents involved in ProMAIS take shape of MAS. They cooperate in order to satisfy the customer, to be more flexible and open to different kinds of orders and to respond quickly to the dynamic changes of external environment to take a position in the market. Thus, we distinguish the main cooperation situations between one or several agencies of agents and we consequently distinguish the cases of emergency orders and those of unexpected risks.

In case of emergency orders, we draw apart the orders hand over by a faithful customer or characterized by a cash payment and the immediate orders. In the first case, the cooperation takes place between the *Monitor* (in particular the *Marketing* agent), the *Planning*, the *Scheduling* and the *Manufacturing* agents. While, in the case of immediate orders, in addition to the agents involved in the last case, the *Stock Management & Procurement* (SMP) agent (in particular the *Finished Product Stock* agent) is added.

In the case of the unexpected risks, we draw apart the cases of a strike, a delay in carrying out a task or in the arrival of raw materials, on the one hand and those of machine breakdown, on the other hand. All these kinds of unexpected risks necessitate a cooperation between different agents involved. In the first case, the cooperation takes place first between the *Manufacturing* and *Scheduling* agents. If the problem is not solved, the *Planning* agent is then involved to cooperate with already montioned agents. If the problem is still not solved (the replanning operation introduces a delay in the deadline of some orders), the *Monitor* agent is involved to cooperate with the others, with the aim to make decisions like the use of the subcontracting, the additional hours or, if it is necessary, the interim hours. In such a case, the strategic decisions already made can be modified. In case of a machine breakdown, the cooperation takes place between the *Manufacturing*, the *Maintenance* and the *Scheduling* agents if the state of the machine is adjustable. However, if the breakdown is serious and cannot be adjusted in a convenient time, the *Monitor* agent is involved with the aim to make quickly the decision to overcome this kind of problem like the use of the subcontracting.

3.3.3 Negotiation protocol

In ProMAIS, we can distinguish two cases of negotiation. The first one appears at the time of the hand-over of an order from a *Customer* agent. The negotiation will take place between the *Customer* agent and the *Monitor* agent regarding the fixing order price. The second one appears at the time of fixing the estimated price of a new product that is conceived by the *Design & Engeneering* agent. This negotiation will take place between the *Design & Engineering* agent and the *Monitor* agent.

3.3.4 Contract Net protocol

The Contract Net is a negotiation protocol proposed by Smith (Smith, 1980). It facilitates distributing subtasks among various agents. The agent wanting to solve the problem broadcasts a call for bids, waits for a reply for some time, and then awards a contract to the best offer(s) according to its selection criteria.

The Contract Net protocol used in our proposed model ProMAIS consists in a process for selecting a supplier for a purchasing operation. For this, the *SMP* agent broadcasts a call for bid for all *Supplier* agents. Each *Supplier* agent thus becoming a bidder sends its bid as regarding price and delay. Even the *Supplier* agents can’t satisfy the order send the same bid message giving the value of (–1) to the price and delay variables. This message is necessary for the learning of the *SMP* agent. For example, if it receives at many times a refusal message from the same *Supplier* agent, the *SMP* agent eliminates the latter from the list of *Suppliers*.

After receiving the propositions (agreement and refusal bids) the *SMP* agent verifies the fund availability through a cooperation with the *Monitor* agent and it will select a *Supplier* agent to perform the purchasing operation according to its criteria (mainly a price and a fund availability for this purchasing operation), and award a contract to it.

4 PROTOTYPE IMPLEMENTATION

The proposed model ProMAIS has been implemented in a simulation form.

This virtual system incorporates heterogenous agents. It is implemented within a multi-agent platform called AgentBuilder Pro 1.3 (Reticular, 2000) which is an integrated tool suit for constructing intelligent software agents. It consists of two major components: the Toolkit and the Run-Time system. All agents are implemented using Java programming language.

Communication among agents was realized using RMI protocol and the inter-agent messages were formatted in KQML (Knowledge Query and Manipulation Languages) format.

In this simulation, the agent execution cycle consists of the following steps: processing new messages, determining which rules are applicable to the current situation, executing the actions specified by these rules and updating the mental model in accordance with these rules.

5 CONCLUSION AND FUTURE WORKS

Manufacturing systems are organizations composed of heterogeneous entities involved in the production and the delivery of finished product or services. Nowadays, the IS for such organization can be viewed as a collection of sub-systems distributed between the different entities. This results in the cooperative information system technology. The entities communicate via computerized data. The manufacturing organization must follow the dynamic of the market and respond quickly to the customers requirements.

The choice of intelligent software agent technology provides a natural way to design such systems because the intrinsic feature of MAS correspond to those to be preserved in the hoped production systems. Autonomy, heterogeneity, openness, cooperation, dynamicity, commitment etc… are at the heart of our reflection.

ProMAIS, provides the integration of different entities (divisions) in manufacturing and production systems. In fact, a cooperative MAS allows each agent to communicate and cooperate with others while conserving its autonomy.

ProMAIS is an ongoing project. A major short-term research goal is to study the position of humans in the system. The long-term research goal tends towards fixing the distribution of the global databases, study the interaction of agents with databases, the resolution of different kinds of conflict resulting from the heterogeneity of data sources and then to implement this approach in a real manufacturing enterprise.

REFERENCES

Balasubramanian, S., Maturana, F.P., and, Norrie, D. 1996. Multi-Agent Planning and Coordination for Distributed Concurrent Engineering. *International Journal of Intelligent and Cooperative Information Systems. Special Issue on Agent Based Information Management*.

Ferber, J., Jacopin, E., 1990. The framework of Eco Problem Solving. *In Proceedings of the 2nd European Workshop MAAMAW'90*. pp. 103-114

Ghedira, K., 1994. Distributed Simulated Re-annealing for Dynamic Constraint Satisfaction Problems. *In Proceedings of the 6th IEEE International Conference on Tools with Artificial Intelligence (TAI94).*

Hayes-Roth, B., 1995. An architecture for adaptive intelligent systems. *Artificielle Intelligent*, pp. 329-365.

Labrou, Y., Finin, T., Peng, Y., 1999. Agent Communication Languages: the current Landscape. *Intelligent Agents IEEE*. pp. 45-52.

Maturana, F. and Norrie, D. H., 1996. Multi-Agent Mediator Architecture for Distributed manufacturing. *Djournal of Intelligent Manfacturing.* pp. 257-270.

Qiao, B., Zhu, J., 1999. Agent-based Intelligent Manufacturing System for the 21st Century. *Mechatronic Engineering Institute.* University of Aeronautics and Astronautics.

Reticular, S., 2000. AgentBuilder: An Integrated Toolkit for Constructing Intelligent Software Agents: Reference Manual. *Version 1.3 Rev. 0. April 11, 2000 Reticular Systems, Inc.* http://www.agentbuilder.com.

Shen, W., and Norrie, D. H., 1998. A Hydrid Agent-Oriented Infrastructure for Modeling Manufacturing Entreprises. *Division of manufacturing engineering.* The University of Calgary, Canada.

Shen, W., Barthès, J.P., 1995. DIDE: A Multi-Agent Environment for Engineering Design. *In Proceedings of the First International Conference on Multi-Agent Systems*. San Francisco, CA, The AAAI press/The MIT press.

Smith, R.G., 1980. The Contract Net Protocol: High-Level Communication and Control in a Distributed Problem Solver. *IEEE Transactions on Computer*. pp. 1104-1113.

Wagner, G., 2000. Agent-Object-Relationship Modeling. *In Proceedings of Second International Symposium "From Agent Theory to Agent Implementation" (AT2AI-2), in conjunction with EMCRS 2000, Vienna.*