Multi-Agent based Negotiation Support Systems for Order based Manufacturers

Hyung Rim Choi, Hyun Soo Kim, Young Jae Park, Byung Joo Park, Yong Sung Park

Department of MIS, Dong-A University
840 Hadan-dong, Saha-gu, Busan 604-714, Korea
Tel: +82-51-200-7477, Fax: +82-51-207-2827, E-mail: hrchoi@daunet.donga.ac.kr

Abstract

In this research, we developed a Multi-Agent based Negotiation Support System to be able to increase the competitive power of a company in dynamic environment and correspond to various orders of customers by diffusion of electronic commerce. The system uses the agent technology that is being embossed as new paradigm in dynamic environment and flexible system framework. The multi-agent technology is used to solve these problems through cooperation of agent. The system consists of six sub agents: mediator, manufacturability analysis agent, process planning agent, scheduling agent, selection agent, negotiation-strategy building agent. In this paper, the proposed Multi-Agent based Negotiation Support System takes aim at the automation of transaction process from ordering to manufacturing plan through the automation of negotiation that is the most important in order-taking transaction.

Keywords

intelligent agents, multi-agent, virtual manufacturing, negotiation, scheduling, sales engineer

1. Introduction

In recent years, the wide-spread of Electronic Commerce(EC) in many areas made new systems and paradigms. Many order-based manufacturers are adequately corresponding to this change, and they need new systems and paradigms to earn a competitive power. Contrary to

the traditional mass productions, order-based manufacturing corporations have a specific character of small- quantity-batch-production.

This character needs an ability to respond more quickly and dynamically to customers' requirements and to change of corporations' circumstances.

In this research, we select a molding industry as our studying domain. Molding is a typical small- quantity-batch-production industry that has to make merchandise according to a variety of customers' orders. This industry needs adoption to a new information technology because of followings. First, It is more important to reduce the time limit for delivery than to develop their own merchandise because molding industry is an order-based manufacturing system satisfying customers' requirement. Second, most of the domestic molding corporation is small scale; 81.5% of 2,500 domestic corporations have less than 20 employees. Third, the lack of experts in the area of programming and system became the cause of decline of productivity.

The process of molding industry is request→analysis of the content of request→negotiation →trade & contract accomplishment→produce.

However, in the analysis of order contents and negotiation, some problems may happen. First, refusal of orders because of the wrong judgement of production possibility. Second, unnecessary overtime works which are not efficient. Third, inappropriate contract and acceptance of order because of unfavorable negotiation.

In this research, we developed a new order processing automation system that can utilize capacity and scheduling data, and behaves as experts in analysis of order contents and negotiation. This system attempted order-taking automation through the automation of negotiation, because negotiation is the most important process among order-based manufacturer's transaction process(Rosenschein and Zlotkin, 1994).

For transaction automation of order manufacturer, we used the agent technology. Agent technology is embossed as a new paradigm that can have competitive power and can cope flexibly and promptly with the customer's order in various-kind-few-produce industry in responding to the environmental change of electronic commerce through all of the order-based manufacturers including smaller enterprises that are relatively insufficient in capital, manpower and technology(Shu and Norrie, 1999). Moreover, agent technology can offer real-time information that is needed for negotiation, and has organic structure which is suitable in changing environment. Furthermore, agent technology has an ability that can take the place of current experts in business.

In this research, a Multi-Agent based Negotiation Support System(MANESS) for order-taking automation of order-based manufacturers is suggested. It uses the agent technology that automates all the trading activities including manufacturing analysis through

negotiation automation. This system is composed of agents such as Manufacturability Analysis Agent, Process Planning Agent, Scheduling Agent, Selection Agent, and Negotiation Strategy Building Agent. The Mediator has the role of connecting and message exchange between the agents and pursues the negotiation activity with the 'Buyers Agents' in an agent-mediated electronic commerce environment. MANESS can correspond to various trading changes that happen during transaction activity as well as standard transaction activity through the cooperation of agents.

This research is composed of 5 chapters. In chapter 2, we give literature review about agent-based manufacturing systems and multi-agent architectures. In chapter 3, we'll offer the whole structure and composition of the multi-agent based negotiation support system. Chapter 4 provides a case study of MANESS and shows the normal and situational system flows. In the last chapter, we'll provide the conclusion with future research directions.

2. Literature Review

2.1 Agent based Intelligent Manufacture Systems

The studies of agent based intelligent manufacturing systems are well reviewed in the study of Intelligent Systems Group from University of CALGARY(Shen et al., 1999). The agents that have various architecture and capacity were reviewed in Shen's study. The main interest of those researches was the development of manufacturing system with efficient process of process planning and scheduling using automatic agents. In these studies, possible methods were suggested which can integrate scheduled activities and the fluctuations on the real spot that couldn't be predicted in advance. That means, the methods are suggested how to deal with the change of circumstances within the time limits when previously decided schedules were invalidated.

In the methods, a resource, such as work cell, instrument, apparatus, worker, and establishment, is an agent that is responsible for the resource scheduling. Those agents work with other agents through the Mediator for the total scheduling.

Besides those studies, the representative studies that use the agent technology to develop the intellectual producing system are AARIA (Autonomous Agents for Rock Island Arsenal) project(Baker et al., 1997) by Intelligent Automation, ABCDE(Agent Based Concurrent Design Environment) by KSI(Knowledge Science Institute) in University of Calgary(Balasubramanian & Norrie, 1995), and The study of virtual producing agent based on multi-agent by LIPS in The University of Texas at Austin(Chuter et al., 1995).

Particularly, most studies include the concept of 'Virtual Manufacturing' that virtually

manufactures before the actual manufacturing to see how it is going.

These researches take advantage of agent technology and develop intelligent system that is necessary for productivity. However, they did not extend the virtual manufacturing to negotiation with traders. There is no research to integrate the automation of manufacturing and automation of negotiation for trade in order-based manufacturing environment. This research is for integrating of manufacturing and negotiation for the order-based manufacturers in front of many buyers who ask for CFQs.

2.2 Multi-agent structure

Recent agent technology was embossed as a new method for developing a manufacturing system. Particularly, multi-agent that made the achievement of the goal through the cooperation among the agents became a new paradigm in producing system area. This is for the coping with the focus on change from static manufacturing circumstances to dynamic circumstances.

There are many studies about the multi-agent for manufacturing system. Multi-agent architectures are classified into Facilitator Architecture, Mediator Architecture, and Autonomous Agent Architecture, as shown in Figure 1 (Shen and Norrie, 1997).

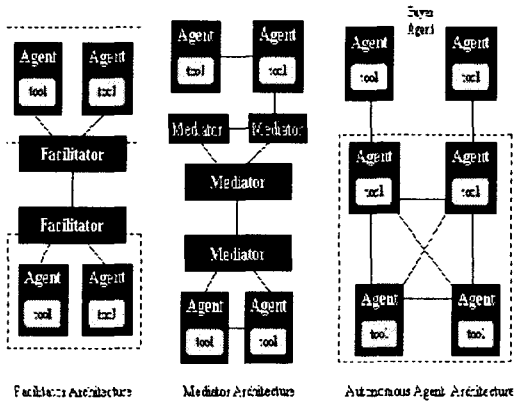

Figure 1. Architecture of Multi-Agent

2.2.1 Facilitator Architecture

Facilitator Architecture, called federation multi-agent architecture is proposed in the project of SHADE(McGuire et al., 1993), and emphasized in the project of PACT(Cutkosky et al., 1993). Facilitator architecture is, as in Figure 1, composed of various agents that have their own knowledge and tools for doing certain functionality. They communicate with other agent

through the facilitator.

Facilitator is a particular agent, it is responsible for providing an intermedium between a local agents and remote agents, usually by providing three main services: (1) routing outgoing messages to the appropriate destinations; (2) providing the trustworthy network interface; (3) simple control and coordinating facilities (Shen et al., 1997).

In the facilitator architecture, each facilitator does not support direct communication among agents but supports communication between facilitator and agents and among facilitators.

2.2.2 Mediator Architecture

Mediator architecture is a special form of federation organization, derived through Blackboard System, Contract-Net(Smith, 1980), Non-explicitly Coordinated Systems, and Supervisor System(Kirn and Schneider, 1992).

Although similar to facilitator architecture, it is more higher dimensional structure that each agents are connected with Mediator. However, as in Figure 2, unlike facilitator architecture, communication between agents and mediator, between mediators, and between agents is possible through brokering and recruiting mechanism. Moreover, besides the role of passing message, mediator does mediating role to enhance cooperation among agents and role of learning each agent's behaviour (Shen & Norrie, 1997).

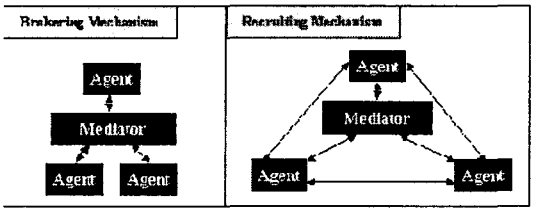

Figure 2. Communication Mechanism of Mediator

2.2.3 Autonomous Agent Architecture

Unlike facilitator architecture and mediator architecture, Autonomous Agent Architecture has an independent structure. Facilitator architecture and mediator architecture is cooperative, in other words, accomplish a purpose by being subordinate to each other. However, Autonomous agent architecture accomplish a purpose by being independent of each other. Autonomous Agent's property is are as followings. (Shen & Norrie, 1997).

- Not controlled by any other agent or people
- Direct communication with any other inner and outer agent is possible
- Have knowledge of other agents and environment
- Each agent has its own purpose and is combined each other by certain motive

DDIE project(Shen and Barthes, 1996) and AARIA project(Parunak et al., 1997) used autonomous agent architecture for constructing intelligent manufacturing system.

The system developed in this research is a Hybrid Architecture that mixed mediator architecture and autonomous agent architecture. If looking at the whole structure, it's mediator architecture. However, if looking at the each interior agent functioning independently, it can be autonomous agent architecture. The structure of this system will be explained in details in Chapter 3..

3. Structure of Multi-Agent based SupportSystems

The Multi-Agent based Negotiation Support System (MANESS) developed in this research is a system to automate order-taking action coupled with manufacturing planning and scheduling focusing on the automation of negotiation. The system consists of a Mediator with the function of negotiation, message interchange and coordination between agents, and Manufacturability Analysis Agent, Process Planning Agent, Scheduling Agent, Selection Agent, Negotiation-Strategy Building Agent related to manufacturing as in Figure 3. These agents perform functions related to manufacturing, and give necessary information to Mediator for negotiation.

As in Figure 3, the MANESS is a mediator architecture. It has simultaneously the property of the Autonomous Agent Architecture since the agents of MANESS have their own function and solve a problem through cooperating with each other. The architecture of MANESS is a Hybrid Architecture of mediator and autonomous agent architecture.

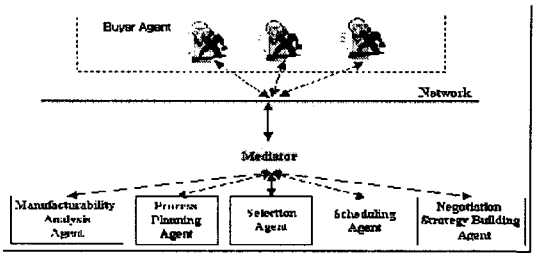

Figure 3. Architecture of MANESS

3.1 Mediator

The Mediator is the core element in MANESS, it can be a decision support system to coordinate the actions of agents. For example, the mediator performs following roles when it accepts the order from a buyer agent. First, it allocates a task to each agent after task division, and sets up the connection to each agent. And it coordinates the process to perform well the task. That is, the mediator is an agent to generalize total process from accepting orders from a buyer agent to replying the result. The roles of mediator are as follows.

- The function of accepting orders and replying the result of order-taking process
- The function of endowing time-bound
- The function of message transmission between agents
- The function of controlling agents
- The function of message filtering
- The function of negotiation

The important function of a mediator is function of endowing time-bound and negotiation. The endowing with time-bound is necessary to coordinate and control agents, also cope with following situation during the negotiation.

- How long does the agent have to wait for a reply?
- By what time should the agent reply?
- How does the agent conclude the finish of negotiation?

Also, The mediator must have the following functions to perform various roles. The function of the mediator is proposed by ISG study of the university of CALGARY (Shen and Norrie,

1998).

- The network interface for connection with buyer agents
- The interface for message transmission and reception from buyer agents
- The knowledge of the mediator action
- The knowledge of each agent's role in system
- The knowledge of the system process
- The reasoning and learning

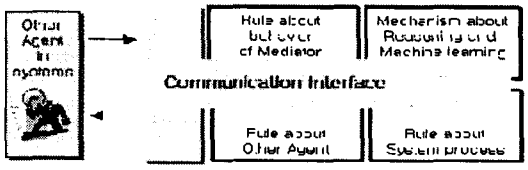

Figure 4. Function of Mediator

The mediator uses knowledge to coordinate, control agents, and interchange messages between agents. The knowledge expressed as rule format is as follows. The first knowledge is for the action when the mediator accepts an order from a buyer agent, the second knowledge is for the action after the mediator accepts a result from the Manufacturability Analysis Agent. The mediator understands the message through the variable named 'contents_name', and then defines its action. The function of the mediator can be extended continuously and can correspond to various situations since the knowledge can be extended.

- When Mediator accepted an order

Rule name Accept Order

if contents_name = order
then ***send*** product_width and product_length and product_hight and raw_material and part_width and part_length and part_hight ***to*** ManufacturabilityAnalysis Agent

● When Mediator received the result from Manufacturability Analysis Agent

```
Rule name  Accept ManufacturabilityAnalysisResult

if                          contents_name          =
ManufacturabilityAnalysisResult                    and
ManufacturabilityAnalysisResult = yes
then send use_for and model_name and number_of_
part and process_time and product_width and
product_length and product_hight and raw_material
and part_width and part_length and part_hight to
Process PlanningAgent
```

3.2 Manufacturability Analysis Agent

Manufacturability Analysis Agent performs the role to decide manufacturability of an order by considering constraints of manufacturing process after receiving information of the product and parts. The constraints are size and weight. The manufacturability is decided by knowledge. The knowledge consists of size and weight capacity of manufacturing facilities and related cases when manufacturing is impossible. An example knowledge for the manufacturability is as follows. Refer (Choi et al., 2000) for details.

'if size of cavity plate is a>600, b>700, c>400, then manufacture is impossibility

```
(constraint_rule_002
  (size_a  ?a), (size_b ?b), (size_c  ?c)

  (if (&& ( ?a 600) ( ?b 700) ) ( ?c 400))
   then (assert (manufacturability no)))
```

3.3 Process Planning Agent

Process Planning Agent is an agent to establish the process planning of the product confirmed by Manufacturability Analysis Agent. It uses Case-Based Reasoning method using data of previous process planning(Choi et al., 2002a). The process planning is complex because a mold has various appearances and characteristics. However, the previous process planning can be used if the use and kind of the mold is similar. The experts in real molding company are using the previous process planning for the process planning of a new mold.

Process Planning Agent receives the information of product and parts, and searches the most similar mold per part. Then, it establishes process planning through adjusting the case if necessity. It uses k-nearest neighbor algorithm to extract the best similar mold. Refer (Choi

et al., 2002a) for details.

3.4 Scheduling Agent

Scheduling Agent establishes a schedule for the selected orders and unselected orders according to request of Selection Agent and Negotiation Strategy Building Agent. The Scheduling Agent establishes the schedule for the selected orders, and then for the unselected orders. The scheduling of unselected orders is performed to obtain the fastest delivery date for negotiations.

Our scheduling model is formulated based on Manne's mixed-integer linear programming(MIP) (Choi et al. 2001). The goal of the scheduling is to minimize completion time for each order.

MIP is good up to the size of an 88 problem(job machine), but it failed to find a solution in larger problems. In the paper, we use the Genetic Algorithm to solve the problem that is known as NP-hard. For details, please refer (Choi et al., 2001; Park et al., 2001).

3.5 Selection Agent

Selection Agent performs the role to select the optimal order set based on process planning and processing time obtained by Process Planning Agent. If it determines that it cannot produce all orders, it selects the optimal order set that are most profitable. The selection method of Selection Agent is based on Manne's Mixed-Integer linear Programming(MIP) (Choi et al., 2001a). In this formulation, the objective function maximized profit while constraints are imposed to satisfy due date requirements.

However, we use the Genetic Algorithm for selecting the optimal order set and scheduling in this paper, because of the limitation of MIP in the larger problems. First, it is defined for representation, initialisation, genetic operators and parameters to use Genetic Algorithm. For the representation of a chromosome, we have adopted an operation-based representation, which is capable of coping with additional constraints of the JSSP. The chromosome is generated by the Giffler and Thompson algorithm. For the crossover operator, we use crossover modified from the techniques of PMX(Partially Mapped Crossover). For the mutation, neighbourhood search-based mutation is used. We can confirm that our GA is more suitable as a scheduling module in agent through many experiments (Choi et al., 2001; Park et al., 2001).

When the scheduling agent accepts new order, the rescheduling should be performed to minimize the completion time of new jobs keeping previous schedule because the due date of

previous jobs are already consented with customers. In this research to keep previous schedule, the incremental scheduling was adopted. The scheduling is performed only for operations of new jobs to get possible start time from the previous schedule. The incremental scheduling can make more quicker schedule. Please refer (Choi et al., 2001) for details.

3.6 Negotiation Strategy Building Agent

The negotiation can make the contract possible for unselected orders that cannot meet their due date by Selection Agent. Thus, the company can make the orders possible and increase sales through negotiation regarding trade-off relationship between price and due date. That is, the company can extend the due date while making down the price.

The negotiation is performed by the Mediator, but Negotiation-Strategy Building Agent provides the list of orders to be negotiated and the price information obtained by price decision function to the Mediator. Negotiation-Strategy Building Agent uses price decision function for a due date as in Figure 5. The price is obtained by following numerical formulas for each due date (Choi et al., 2002b).

- Normal price{excess due date x (manufacturing variable cost/excess due date)}
- Normal price{excess due date x (manufacturing variable cost^2/excess due date)}
- Normal price{excess due date x (manufacturing variable cost/excess due date)}

The excess due date is the difference between revised(negotiable) due date and required due date. The manufacturing variable cost is a supplementary appropriation by overtime and so on for observing due date.

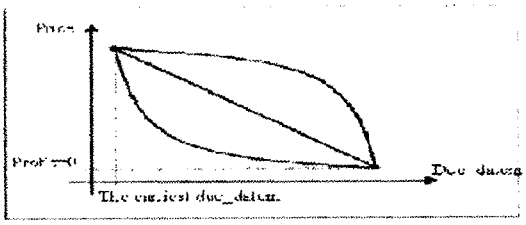

Figure 5. Price Decision Function of Negotiation- Strategy Building Agent

4. Case Study

MANESS developed in this research respond not only general transaction activity but also various changes that happen among transaction activity to execute the order through the cooperation of each agents in MANESS. This cooperation is made through communication among agents using KQML, which is the representative communication language among agents (Finin et al., 1994).

In this chapter, we explain that the message format to interchange among agents and total process of MANESS and how to respond in various situational changes that happen among transaction activity through the cooperation of each Agents.

4.1 Construction of Messages and Exchange Protocol

We define the message interchange format among Agents in MANESS as shown in Table 1. Each agent select messages needed to discharge its own function and interchange the message.

Order_Number	- The number distinguished orders - When accept the order, Mediator give number		
Company Information	- Company name - url address		
Product Information	- Use - Product_name - Model_name	-Process_time -Mold_structure -Number_of_parts	-Size
Parts Information	- Parts_name	-Raw_material	-Size
Time-Bound	- Mediator gives time-bound to each order-		

Table 1. Composition of Message

As in Table 1, the message composed of five categories such as Order- Number, Company-Information, Product-Information, Part-Information, Time-Bound.

Tine-Bound offered by Mediator have its origin in Time-Bound Negotiation Framework where agents negotiate through messages with commitment duration (denoted by T). During the T, agents have to reply to other agents (Lee et al., 2001).

4.2 System Flows

4.2.1 Total Process Flows

Figure 6 represents standard process of MANESS where Mediator accepts three orders offered by each Buyer Agent. We used Sequence Diagram of UML to represent how agents in MANESS deal with the orders and prove that there is no bottleneck in the process. The standard process is a process where there is no situational change while dealing with orders.

Step1: Accept Orders

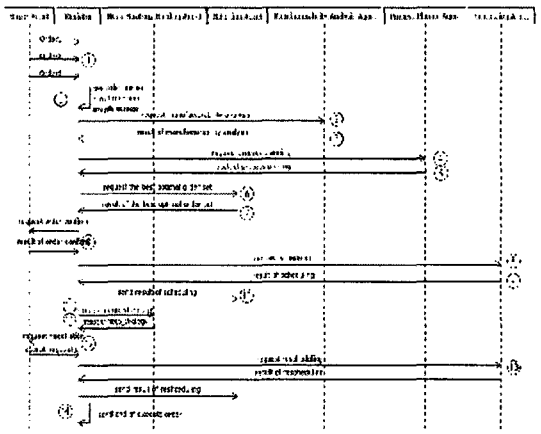

Figure 6. Total process design using UML (Sequence Diagram)

(1) Mediator receives an order message which include business information, product information, parts information, the time limit for delivery, Time-Bound from Buyer Agent 1, Buyer Agent 2, Buyer Agent 3, and gives order numbers and analyses the massage.

Step 2: Manufacturability Analysis

(2) Mediator request Manufacturability Analysis to Manufacturability Analysis Agent about each orders. Mediator passes the massage that includes order number, product information, part information, time-bound to Manufacturability Analysis Agent.

(3) Manufacturability Analysis Agent assorts the possible orders and pass the massage that includes order number and analysed result of manufacturability information to Mediator. If

manufacturing is impossible, then it passes the message with impossible code.

Step 3: Process Planning

(4) If three orders are all possible, Mediator passes the massage to Process Planning Agent which include order number, product information, parts information, and Time-Bound then ask to make a process plan.

(5) Process Planning Agent makes a process plan of each orders and pass the message that include order number and information of a process plan to Mediator.

Step 4 : Select the best optimal order set

(6) Mediator passes the massage that include main statement number, information of a process plan, the time limit for delivery, and time-bound to Selection Agent and ask the best optimal order set.

(7) Selection Agent assorts the best optimal orders within manufacturing capacity and passes the massages that include order number of the best optimal order set to Mediator.

Step 5: Confirm the order

(8) After Mediator does the last contract with Buyer Agent, it passes the massages that include order number, process plan information, and time-bound to Scheduling Agent and requires scheduling. Thereafter, it transmits the same message about orders that are not chosen and request scheduling together.

Step 6: Establishing the schedules

(9) After Scheduling Agent establishes the schedules for the chosen order, it passes the massage that contains the order number and schedule information. Thereafter, it establishes the schedule for the unchosen orders, and passes the massage that contains order number and the shortest delivery date information to Mediator.

(10) Mediator passes scheduling information to Selection Agent for keeping. And it requests negotiation strategy establishment about the order that are not chosen by passing the massage which contains the order number and the earliest delivery date due information to

Negotiation Strategy Building Agent.

Step 7: Build a negotiation strategy

(11) Negotiation Strategy Building Agent establishes negotiation strategy and transmit message of price decision information for the earliest delivery date to Mediator.

Step 8: Negotiation

(12) Mediator passes the massage that contains name of company, the name of product, negotiation message, and Time-Bound to Buyer Agent to negotiate with Buyer Agent whose order is not chosen based on price for the earliest delivery date that Negotiation Strategy Building Agent establishes

(13) When negotiation goes well and the order is contracted, Mediator passes the massage that contains the order number and schedule information to Scheduling Agent to establish the schedule. Then Mediator passes the schedule information that is established by Scheduling Agent to Selection Agent.

Step 9: Finishing the order

(14) When all the jobs related to the accepted orders end, Mediator informs to all inner agents the finish.

The process explained above is the standard process. However, manufacturers are facing with changes happening in various situations and among transaction activity to process the order.

- While processing an order, if new order is received, do they have to be processed together or sequentially?
- While negotiating for an order, if new order is received, do we have to accept the new one and negotiate together or postpone it?
- When many orders arrived at a same time, do we have to process all of these concurrently or select and process just a few orders?

- Among received orders, which one is going to generate the best profit?
- When order contents are changed, how do we adjust the process plans and schedules to finish the orders?
- When there is a problem in your machine or worker, how to respond this problem?

MANESS can correspond to various changes through each agent's abilities and cooperation and Mediator as a central figure. When they found some changes, each agent composing the MANESS cooperates with each other agent through communication to correspond to the changes.

Figure 7 is snapshot of interface monitoring interchange messages among agents for cooperation. This communication interfaces are developed using JAVA and JATLite that is a framework for interchange messages among agents and developed in the Stanford University (Jeon et al. 2000).

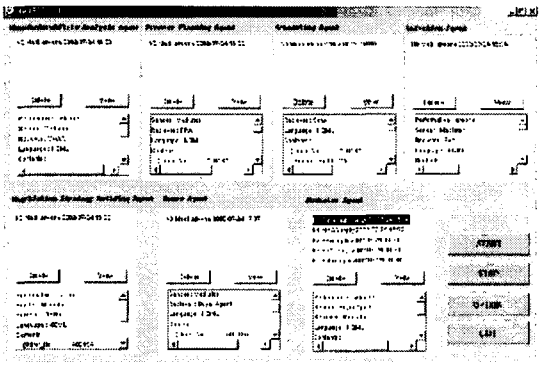

Figure 7. Message Exchange Interface between the Agents

4.2.2. Situational Case

In this chapter, we explain that how MANESS responds to various environmental change that happen during transaction activity to execute orders. The most frequent situation is that new orders are received while doing for existing orders or negotiating with Buyer Agent. Figure 8 presents the process of MANESS responding to following situational case using the Sequence Diagram of UML

Case) After scheduling of the selected orders, Mediator receives new order while negotiating for the unselected orders with buyer agent

(1) Mediator makes the negotiation standby.

(2) Mediator requests manufacturability analysis to Manufacturability Analysis Agent and process planning to Process Planning Agent for the new order. And it requests for selecting the optimal order set from new and the unselected orders to Selection Agent.

(3) If the profit of the new order is higher than those unselected orders, cancel the negotiation for the unselected orders and Mediator commands all agents in MANESS to execute the new order

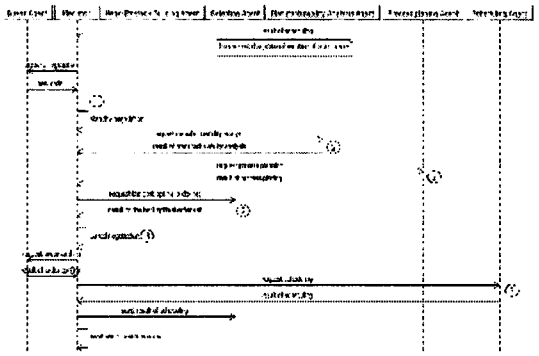

Figure 8. Situational Scenario: New Order is Received while Executing a Negotiation

MANESS can respond not only to the above situation but also to various environmental changes that happen during transaction activity.

5. Conclusion

In this paper, we have proposed and developed a multi-agent based negotiation support system. The system automates the negotiation process that is the core function in trading activity of order-based manufacturers. The multi-agent system includes such agents as manufacturability analysis agent, process planning agent, scheduling agent, selection agent, negotiation-strategy building agent to supply production information necessary for negotiation.

The synchronized information between production part and business part in a company is very necessary for successful order-taking and negotiation for a order-based manufacturer. A sales engineer who knows both of production and business information is in the charge of coordination in the field. However, such expert personnel are rare and even he/she may have to be supported by intelligent systems for scheduling, tracing, planning and negotiation

strategy building with the functions of auto-configuring for the dynamic situation.

The system in this paper can act the role of a sales engineer by pooling and coordinating relevant agents to maximize the business object within the finite production capacity.

This system considers the dynamic nature of order-taking process in agent-mediated electronic commerce environments.

The future research subject will be how to formalize the variety of dynamics and methodology to deal more complex situation and to extend the scope to a broader supply chain environment.

References

[1] Baker, A. D., H. V. D. Parunak and K. Erol(1997), "Manufacturing over the Internet and into Your Living Room: Perspectiv es from the AARIA Project," *ECECS Dept., Technical Report* TR208-08-97.

[2] Balasubramanian, S. and D. H. Norrie(1995), "A Multi-Agent Intelligent Design System Integrating Manufacturing And Ship-Floor Control," URL:http://ksi.cpsc.ucalgary.ca /projects/mediator.

[3] Chuter, C. J., S. Ramaswamy and K. S. Barber(1995), "A Virtual Environment for construction and Analysis of Manufacturing Prototypes," URL:http://www.cs.umd.edu/~regli/asme.ps.

[4] Cutkosky, M.R., Engelmore, R.S., Fikes, R.E., Genesereth, M.R., Gruber, T.R., Mark, W.S., Tenenbaum, J.M. and Weber, J.C(1993), PACT: An Experiment in Integrating Concurrent Engineering Systems, *IEEE Computer*, vol. 26, no. 1(1993). 28-37

[5] Finin, T., Fritzson, R., Mckay, D., and McEntire, R.(1994), KQML as an Agent Communication Language, Proceedings of the Third International Conference on Information and Knowledge Management (CIKM'94)..

[6] Choi, H. R, H. S. Kim, C. H. Lee (2000), "Development of a Virtual Manufacturing Agent in EC Market Place, *Proceedings of the 31st Annual Meetings of the Decision Science Institute*, Vol. 2, pp.497-499.

[7] Choi, H. R. H. S. Kim, Y. J. Park, B. J. Park(2001), "An Agent for Selection Optimal Order Set in EC Marketplace," *Proceedings of the Pacific Asia Conference on Information Systems*, pp.490-508.

[8] Choi, H. R., H. S. Kim, Y. S. Park(2002a), Intelligent Injection Mold Process Planning System Using Case-Based Reasoning, *Journal of Intelligent Information Systems*, (in Korean), vol. 8, no. 1, pp.159-173.

[9] Choi, H. R. H. S. Kim, Y. J. Park, B. J. Park(2002b), A Negotiation Agent for Order Transaction in Electronic Commerce Environment", *INFORMS Annual Meeting.*

[10] Jeon, H., C. Petrie, M. R. Cutkosky(2000), "JATLite: A Java Agent Infrastructure with Message Routing," *IEEE Internet Computing.*

[11] Kim, H. S., H. R. Choi, B. J. Park, Y. J. Park, Y. S. Park(2002c), Development of a

Web-based Scheduling Agent for a Small Injection Molding Company, *The Journal of KASBIR*, (in Korean), vol. 2, no. 1. pp.51-58.

[12] Kirn, S. and Schneider, J.(1992), STRICT: selecting the right architecture, *Industrial and Engineering Applications of Artificial Intelligence and Expert Systems*, Lecture Notes in Artificial Intelligence 604, Belli, F. and Radermacher, F.J. (eds.), pp.391-400.

[13] Lee, K. J., Y. S. Chang, H. R. Choi, Y. J. Park, B. J. Park (2001), "Negotiation and Decision Making of Virtual Manufacturing Agent under Time-Bounded Environment," *Proceedings of International Conference on Electronic Commerce,* CD-ROM.

[14] McGuire, J., Kuokka, D., Weber, J., Tenenbaum, J., Gruber, T. and Olsen, G.(1993), SHADE: Technology for Knowledge-Based Collaborative Engineering,† *Journal of Concurrent Engineering: Application and Research*, vol.1, no. 3.

[15] Park, B. J., H. R. Choi and H. S. Kim (2001) A Hybrid Genetic Algorithms for Job Shop Scheduling Problems, *The Genetic and Evolutionary Computation Conference*, pp. 317-324.

[16] Parunak, H.V.D., Baker, A.D. and Clark, S.J.(1997), the AARIA Agent Architecture: An Example of Requirements-Driven Agent-Based System Design,† *In Proceedings of the First International Conference on Autonomous Agents*, Marinadel Rey,CA.

[17] Rosenschein, J. and Zlotkin, G.(1994), "Rules of Encounter: Designing Conventions for Automated Negotiation among Computers" *MIT Press.*

[18] Shen, W., Norrie, D.H., and Kremer, R.(1999), "Developing Intelligent Manufacturing Systems Using Collaborative Agents," *Proc. of the 2nd International Workshop on Intelligent Manufacturing Systems*, Leuven, Belgium, pp. 157-166.

[19] Shen W. & Norrie D.(1997), Facilitator, Mediator or Autonomous Agents, *In Proceedings of the Second International Workshop on CSCW in Design*, Bangkok, Thailand. pp. 119-124.

[20] Shen, W. and Barthes, J.P.(1996), An Experimental Multi-Agent Environment for Engineering Design,† *International Journal of Cooperative Information Systems*, 5(2-3), pp. 131-151.

[21] Shen, W. and Norrie, D.H.(1998), A Hybrid Agent-Oriented Infrastructure for Modeling Manufacturing Enterprises, *In Proceedings of KAW'98*, Banff, Canada.

[22] Shu, S., Norrie, D.H.(1999), "Patterns for Adaptive Multi-Agent Systems in Intelligent Manufacturing," *Proc. of the 2nd International Workshop on Intelligent Manufacturing Systems*, Leuven, Belgium. pp. 67-74.

[23] Smith, R.G.(1980), The contract net protocol: high-level communication and control in a distributed problem solver, *IEEE Transaction on Computers*, vol. 29, no. 12, pp. 104-1113.