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A Development of Multi-Agent based Automated Negotiation System

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Abstract

Nowadays, many researches are being made for the development of new transaction system in an effort to transform current off-line system into on-line one. However, these researches mainly focuses on ordinary commercial transaction system, i.e. the one that supports fixed price transaction, in which consumers usually ought to buy goods at the price offered by sellers. Accordingly, more studies are to be made for the system to support both buyers and sellers in searching the proper price level through negotiations.

Under current e-commerce environment, an automated negotiation system is badly needed to respond quickly and flexibly to the diverse environmental changes and also to perform many negotiations consistently and effectively. To this end, this paper has developed a multi-agent based automated negotiation system. This new system creates multi-issue negotiation proposals automatically, evaluating the counterpart's proposal, and then, if necessary, preparing and sending counter proposals time and again, and finally accepting or rejecting.

Keywords: Negotiation; Automated Negotiation System

1. Introduction

Along with the rapid spread of computers and Internet, traditional off-line transaction systems are quickly being transformed into online systems not only quantitatively but also qualitatively. However, this change into the online system has usually been made in the ordinary transaction depending only on the price level, namely, auction or fixed price transaction, but not in the multi-issue negotiation transaction.

Also, most preceding studies on the negotiation systems are not for an automated negotiation system, but for an NSS (Negotiation Support System) that supports the negotiations between buyers and sellers. The reason is that in case of multi-issue negotiation,

it is not easy to evaluate many negotiation issues, consequently making it difficult to develop an automated negotiation system.

However, under current e-commerce environment an automated negotiation system is critical in dealing with complex problems and diverse changes in business environment. If negotiations are active in the e-commerce, numerous negotiations will be made explosively and simultaneously, and so people won't be able to handle them. Therefore, to perform this task on an ongoing basis and efficiently, an automated negotiation system is absolutely necessary.

Carrie and Segev (Beam 1997) emphasized in their studies the importance of "ontology and strategy" to support an automated negotiation. Ontology is a kind of classification method giving a meaning to the software agent. Ontology defines the relationship between similar products.

Strategy means an analysis of the counterpart's negotiation strategy, thus fathoming his negotiation proposal, and offering a responding proposal. To give an example, if the counterpart responds to the price very sensitively, he will yield to the price level the partner wants. Instead, he will try to acquire in a better condition other negotiation issue such as a due date that he considers important.

Accordingly, in order to support ontology and strategy, a multi-agent based negotiation system, which considers multiple negotiation issues, while analyzing his partner's inclination to stir up negotiations, is badly needed. This paper is dealing with a simple problem with the agents of common attribute that doesn't need lots of classification. This means that this study focuses on strategy rather than ontology in the development of an automated negotiation system.

The second chapter of this paper tries to define the concept of both negotiation support system (NSS) and automated negotiation system, analyzing existing automated negotiation systems, and showing its results. The third chapter suggests a newly developed automated negotiation system and its structure and detailed function. Chapter 4 has introduced a real case to test the validity of this system, and finally chapter 5 comments on the contributions of this automated negotiation system and further studies to be done.

2. Analysis of Existing Negotiation Systems

At present many researches are in progress to support negotiations based on an online system. These studies can be divided in two: one is an automated negotiation system that doesn't need human intervention and the other one is the NSS to support the whole process of negotiation instead of automation. Most automated negotiation systems are based on a multi-agent based system. Among them Kasbah (Chaves et al. 1996) and Tete-a-Tete [7] of MIT are typical ones.

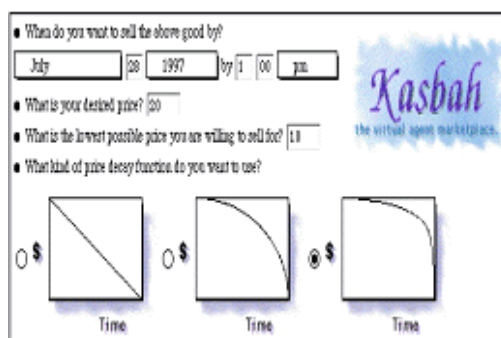
Kasbah (<http://kasbah.media.mit.edu>) is a multi-agent based C2C system, and creates agents for the products to buy and sell, and supports the negotiations automatically through these agents. As shown in the figure 1, the agents of Kasbah input the initial proposal price and final proposal price suggested by the buyer and the seller, define the closing time of negotiation, and then selecting the decrease (increase) function to proceed with negotiations automatically.

Kasbah is an automated negotiation system to help agents enter into negotiations automatically, but as it deals with only one negotiation issue, i.e. price, it has a limitation to the cases of handling multi-issue negotiations. Also, its agent doesn't prepare a negotiation strategy, but the user directly analyzes his counterpart's inclination and inputs his negotiation strategy.

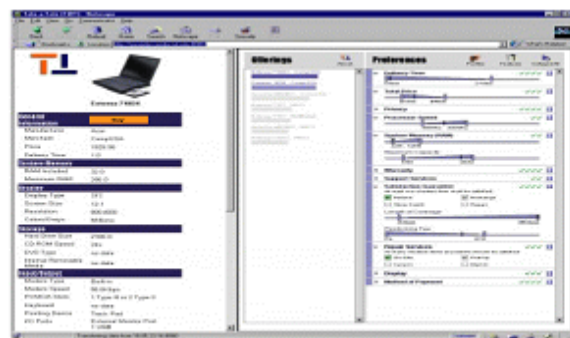
Tete-a-Tete (<http://ecommerce.media.mit.edu/tete-a-tete>) is a more advanced automated negotiation system than Kasbah. Kasbah has only one negotiation issue - price, but Tete-a-Tete has, as shown in the figure 2, diverse kinds of negotiation issues – warranty, delivery time, service contract, return policy, loan options, gift services and merchant value-added services, and continues to proceed with negotiations, while coordinating his preference to the negotiation issues.

Tete-a-Tete evaluates the counterpart's negotiation proposal by capitalizing on the effectiveness of multiple attributes already input by its user, and coordinates his preference based on this effectiveness, thus preparing and suggesting his new proposal to the other side. However, Tete-a-Tete should select the domain to determine its negotiation issues in advance, and so it has a limitation in supporting diverse domains. Also, like Kasbah, it needs human intervention in the negotiations. That is to say, the user ought to prepare negotiation strategy and then input it to the agent.

<Figure 1> Kasbah



<Figure 2> Tete-a-Tete



Source: Maes, P., Guttman, R.H. and Moukas, A.G. "Agent that Buy and Sell: Transforming Commerce as we Know It," MIT Media Lab, March 1998

As shown in the above, Kasbah and Tete-a-Tete, as representative automated negotiation systems, have made great contributions to other studies in the same field. However, the agents of these two systems don't create their negotiation strategies automatically, but their users input the strategies. But the new automated negotiation system developed by this paper analyzes the results of previous negotiations, automatically creates negotiation strategies, based on these strategies evaluates the counterpart's proposal, and then creates and sends responding proposals. Namely, it means the automatic performance of negotiations without human intervention.

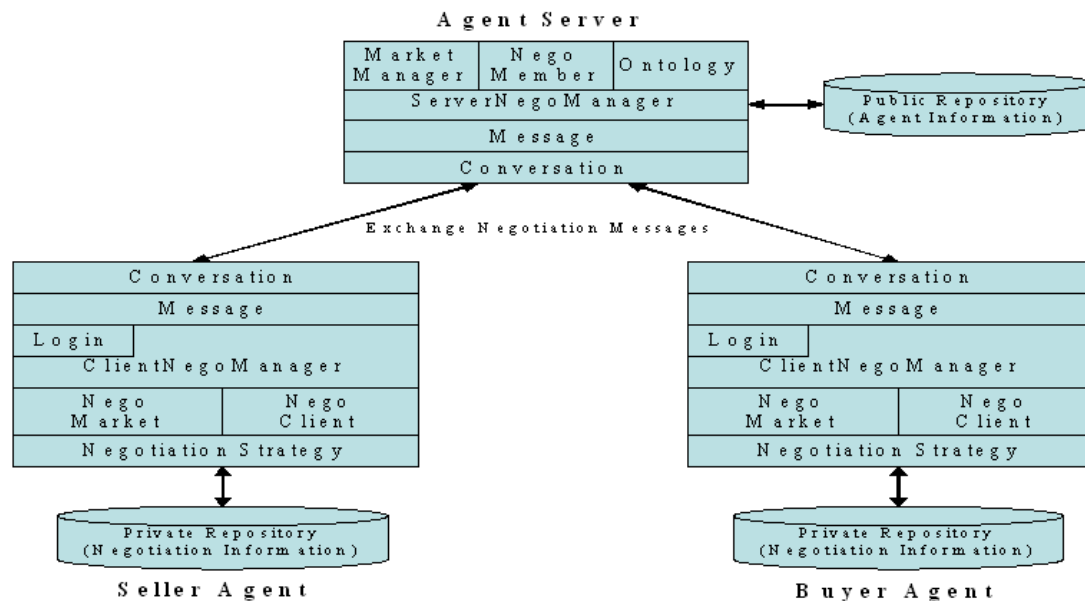
3. MANS (Multi-agent based Automated Negotiation System)

3.1 Structure of MANS and Detailed Functions

While overcoming the difficulty of automatic creation of negotiation strategies, which is also the limitation of Kasbah and Tete-a-Tete, the MANS provides the function of evaluating and composing negotiation proposals. In addition, it provides an agent server to support negotiations between agents.

Basically, the agent and agent server prepare its negotiation proposals in the message class, and then exchange them through conversation class. The agent server parses received messages through ServerNegoManager, and the agent parses messages through ClientNegoManager. Also, they provide responding acts to the messages. MANS is based on

the MAFNS (Multi-Agent Framework for Negotiation System) suggested by Choi, et al. (Choi 2003), and its detailed structure and class are as shown in the <Figure 3>.



<Figure 3> Structure of MANS and Its Detailed Class

■ AgentServer

Agent server authenticates agents and mediates the message exchange between agents. The created agents are to be registered in the NegoMember class, also automatically registered in the waiting room of MarketManager class. ServerNegoManager supports not only the creation of agent, but also mediates the exchange of negotiation proposals between agents, while supporting the agent's registration in the server.

■ Agent

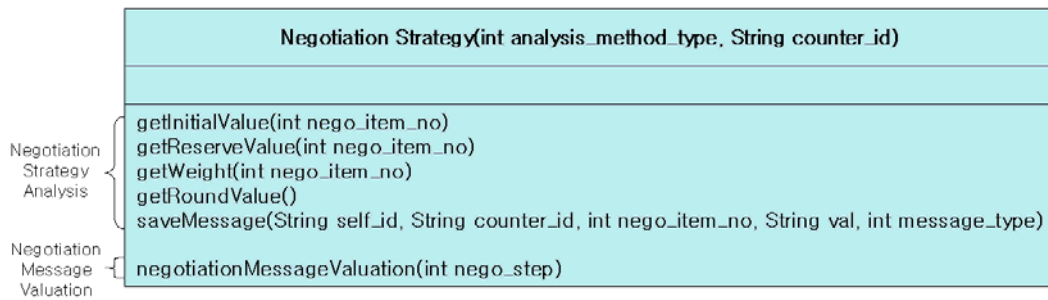
Negotiator links with AgentServer and searches his negotiation partner to enter into negotiation. Negotiator connects with AgentServer through Login class. The waiting room information of agent server can be seen in the NegoMarket class, thus making it possible to search a negotiation partner. He can exchange proposals with his partner through NegoClient, while automatically continuing negotiations. Automated negotiation will go on along with the request of negotiation strategy and evaluation of negotiation proposal through NS (Negotiation Strategy) class.

3.2 NS (Negotiation Strategy)

The MANS developed by this paper basically provides the environment capable to exchange negotiation proposals, registering the agent that is to analyze the counterpart's propensity and create his own strategy, while evaluating the counterpart's proposal. All this analysis and evaluation functions are supported by NS class.

NS is divided into two functions: analysis of negotiation strategy and evaluation of negotiation proposal. First, the analysis function is conducted to fathom both the counterpart's strategy and his own strategy. For this purpose, it has the storage function to save the current proposals in progress and the previous results of negotiations. It also has the function to create new strategies based on the value in storage. Secondly, the evaluation function makes a comparison between his proposal and the other side's proposal, and finally

decides whether to accept or reject. This MANS is adopting MADM (Multi-Attribute Decision Making) to evaluate multi-issue negotiation proposals.



<Figure 4> Detailed Method of NS

NS is the class to support the creation of negotiation strategies and the evaluation of negotiation proposals. As mentioned earlier, MANS analyses the negotiation strategies and evaluates the other side's proposals based on the MADM. The detailed method is as follows.

- NegotiationStrategy(int analysis_method_type, String counter_id)
 - Creator of NS
 - Evaluation method (analysis_method_type) and the counterpart's ID (counter_id) are necessary for parameter.
- getInitialValue(int nego_item_no)
 - The initial value is suggested based on the newly created negotiation strategy
 - Return the initial value corresponding to the number of negotiation item (nego_item_no).
- getReserveValue(int nego_item_no)
 - Suggest the reserve value according to the negotiation strategy
 - Return the reserve value corresponding to the number of negotiation item (nego_item_no).
- getWeight(int nego_item_no)
 - After analyzing the preceding negotiations, it produces the relative weight of each negotiation item automatically.
- getRoundValue()
 - After analyzing the counterpart's negotiation propensity, it decides how many times it will have negotiations and then return them.
- negotiationMessageValuation(int nego_step)
 - Evaluate the other side's negotiation proposal.
 - Return "true" in case of accepting the other side's proposal, and return "false" in case of rejecting it.
- saveMessage(String sender_id, String receiver_id, int nego_item_no, String val)
 - Store up all the negotiation proposals in the DB.
 - Later analyze the previous results to create negotiation strategies and evaluate proposals.

To make a comparison between one's own negotiation proposal and the counterpart's proposal, this paper has used MADM(Yoon 1980;, Keeney 1976). MADM formalizes each negotiation item, which has different criteria, on the basis of uniform criteria, and suggests the evaluation value of each alternative. Each item has a subjective weight that makes it easy to search the best alternative. In order to apply MADM to this paper, the marks have been defined as follows:

n : number of total attributes ($n=2$)

m : number of total negotiation proposals ($m=2$)

A_i : i th negotiation proposal, $i=1, 2$ (1: counterpart's proposal (buyer), 2: his own proposal (seller))

C_j : j th attribute, $j=1$ delivery date, $j=2$ price

x_{ij} : the value of negotiation proposal A_i against C_j , the price and delivery date at the i th negotiation proposal

$$D = \begin{matrix} & \begin{matrix} C_1 & C_2 \end{matrix} \\ \begin{matrix} A_1 \\ A_2 \end{matrix} & \begin{bmatrix} x_{11} & x_{12} \\ x_{21} & x_{22} \end{bmatrix} \end{matrix}$$

p_{ij} : formalized value of x_{ij} by attribute in the section $[0, 1]$, $i=1,2, j=1,2$

E_j : entropy value of p_{ij} against C_j , $0 \leq E_j \leq 1$, $j=1, 2$

d_j : the degree of diversity as for the information provided by evaluation value of C_j , $d_j=1-E_j$, $j=1,2$

s_j : negotiator's subjective weight after considering the attributes, $0 \leq s_j \leq 1$, $j=1,2$

w_j : formalized value determined by d_j , $0 \leq w_j \leq 1$, $j=1,2$

W_j^* : the weight of each attribute based on the entropy criteria, $0 \leq W_j \leq 1$, $j=1,2$

S_i : the total value of p_{ij} multiplied by W_j^* , $i=1,2, j=1,2$

In the MADM, the following formulas are used to calculate the weight conversion and entropy value.

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^m x_{ij}} \quad \text{<Formula 1>}$$

$$E_j = -k \sum_{i=1}^m p_{ij} \ln p_{ij} \quad (k \text{ is a constant, } 1/(\ln m)) \quad \text{<Formula 2>}$$

$$d_j = 1 - E_j \quad \text{<Formula 3>}$$

$$w_j = \frac{d_j}{\sum_{j=1}^n d_j} \quad \text{<Formula 4>}$$

$$W_j^* = \frac{s_j w_j}{\sum_{i=1}^n s_i w_i} \quad \text{<Formula 5>}$$

When the seller has received the buyer's negotiation proposal, he makes a comparison between his proposal and the buyer's based on the MADM as shown in the <Table 1>.

<Table 1> Comparison of Negotiation Proposal

Attribute Message	Negotiation Message	
	C_1 (due date)	C_2 (price)
A_1 (Buyer's Message)	x_{11} (20days)	x_{12} (20000)
A_2 (Seller's Message)	x_{21} (23days)	x_{22} (18000)

In the table 1, A₁ has the two value of delivery date of 20 and the price of 20,000 as his proposal. A₂ has the delivery date of 23 and the price of 18,000 for his proposal. However, as the delivery date and the price have different criteria, these two must be converted into uniform criteria based on the entropy formula to compare them. In order to use entropy formula, the formalized value {p_{ij}} first must be calculated. And substitute D for <Formula 1> to calculate the formalized value {p_{ij}} of x_{ij}, and followed by <Formula 6>.

$$P = \begin{pmatrix} 0.4 & 0.526 \\ 0.6 & 0.474 \end{pmatrix} \quad \text{<Formula 6>}$$

This matrix P is to solved by <Formula 2, 3, 4, 5>, and regarding the price and delivery date, the buyer's E_j, d_j, w_j, s_j, W_j^{*} are to be calculated.

<Table 2> Calculation by MADM

	C ₁ (due date)	C ₂ (price)
E _j	0.97095	0.99804
d _j	0.02905	0.00196
w _j	0.93679	0.06321
s _j	0.55	0.45
W _j [*]	0.94768	0.05232

Now by using entropy value and the SAW (Simple Additive Weighting Method) of <Formula 7>, the negotiation proposals (A₁ and A₂) of both buyer and seller are to be valued and compared.

$$A^* = \left\{ A_i \mid \max_i \left(\sum_{j=1}^n W_j^* p_{ij} / \sum_{j=1}^n W_j^* \right) \right\} \quad (A^* \text{ is optimal solution}) \quad \text{<Formula 7>}$$

According to the definition of S_i, the result of the buyer's proposal evaluation (S₁) is 0.40659232, and the seller's evaluation result (S₂) is 0.59340768. As S₁ is smaller than S₂, then optimal solution(A*) is A₂ according to <Formula 7> and the seller rejects the buyer's proposal. As shown in the above, NS suggests the results of evaluation to the agents, and the agents make a decision of yes or no based on these results.

4. Case Study

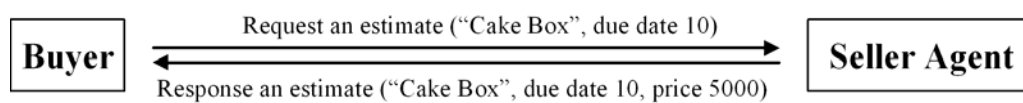
4.1 Definition of Problem

In order to test the validity of MANS, this paper has conducted a real case study. As an object of the case application, an injection-molding company was selected. Molding company is usually based on the multi-item, small-quantity based production system, and also depends on custom-made system. Therefore, contracts are mainly made through negotiations. The key factors of negotiation are due date and price, and these two factors have trade-off relationship. As for the seller, they belong to a "benefit" account and as for the buyer to a "cost" account. These key factors have been applied to the seller's agents for automated negotiation, while the buyer has joined the negotiation without creation of his agent. We conducted price and due as negotiation factors because the most important negotiation factor in an injection-molding company is the price and due date. However, in this research, MANS is able to consider variable negotiation factors. In case of MADM that is used to evaluate

negotiation in this system, it is methodology that can evaluate and compare various attributes. In this research, we developed prototype on the basis of JAVA and applied concrete negotiation problem to present adequacy of methodology application and possibility of real application.

4.2 Performance of Automated Negotiation

Before entering into negotiations, the buyer requests the seller's agent to suggest an estimate based on the specification and due date of the molding product he wants to buy. At this, considering his production environment and capacity, the seller prepares cost accounting and then sends his estimate to the buyer. As shown in the figure 5, the buyer has asked the seller to produce "cake box" molding by the due date of 10, and then received the estimate from the seller agent at the price of 5,000.



<Figure 5> Request of Estimate and Its Result

The seller's agent has sent his estimate to the buyer and analyzed the buyer's negotiation inclination, thus deciding to conduct negotiations ten times, while preparing his negotiation proposals with the price ranging from 4,900 to 4,000 and the due date from 11 to 20. And it has also decided to send them in sequence. Meanwhile, after analyzing the previous negotiations considering the preference of price and due date, the seller's agent has calculated the weight value with the price of 0.45 and the due date of 0.55.

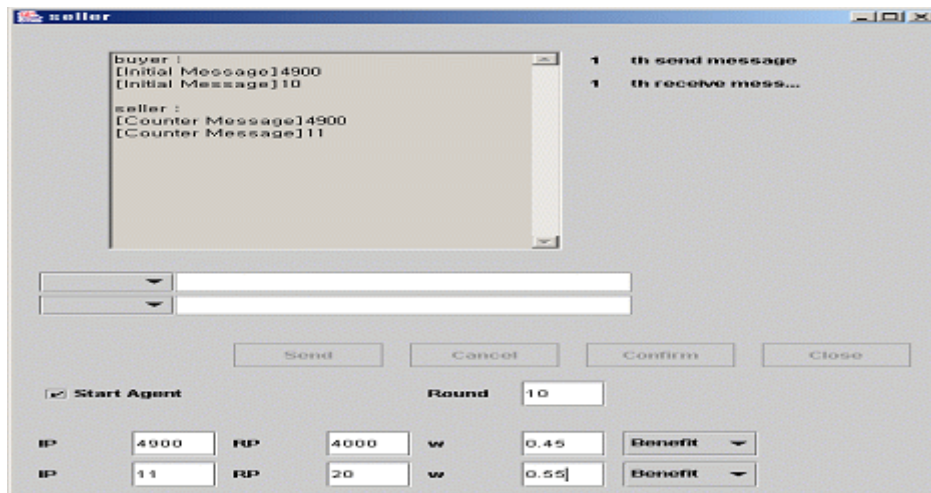
<Table 3> Negotiation Strategy of Seller's Agent

Round	Price(0.45)	Due Date(0.55)	Round	Price(0.45)	Due Date(0.55)
1	4900	11	6	4400	16
2	4800	12	7	4300	17
3	4700	13	8	4200	18
4	4600	14	9	4100	19
5	4500	15	10	4000	20

As for the seller agent's estimate - price: 5,000 and due date: 10, the buyer thinks the price is high, so he suggests the price at 4,900. The seller agent makes a comparison between his proposal and the buyer's one according to his negotiation strategy. As a result, he offers his next proposal –price: 4,900 and due date: 11 to the buyer.

<Table 4> Negotiation Results of 1st Round

Round	Seller Agent			Buyer		
	Price	Due Date	MADM Result	Price	Due Date	MADM Result
1	4900	11	1.0	4900	10	0.9499372

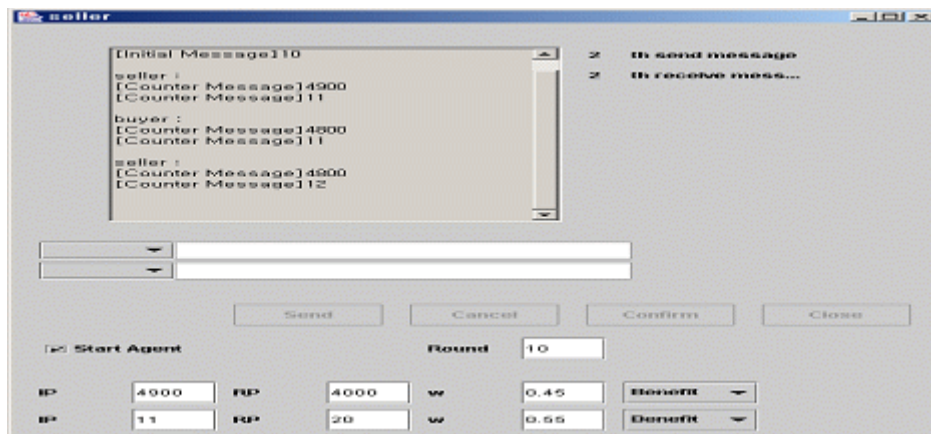


<Figure 6> Negotiation Screen of 1st Round

In the 2nd round, as for the seller agent's proposal – price: 4,900 and due date: 11, the buyer sends his counter proposal – price: 4,800 and due date: 11. At this, the seller's agent values the buyer's proposal below his proposal based on his negotiation strategy. So, he sends his third proposal.

<Table 5> Negotiation Results of 2nd Round

Round	Seller Agent			Buyer		
	Price	Due Date	MADM Result	Price	Due Date	MADM Result
1	4900	11	1.0	4900	10	0.9499372
2	4800	12	1.0	4800	11	0.95411867

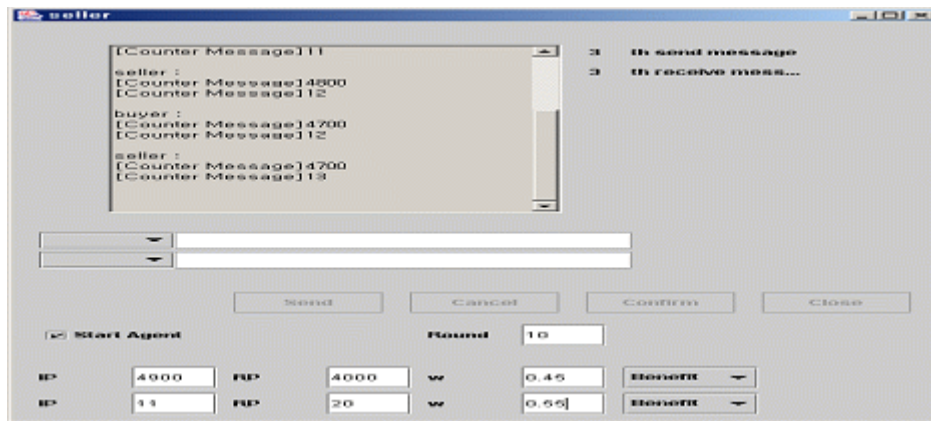


<Figure 7> Negotiation Screen of 2nd Round

In the 3rd round, the buyer is again not content with the seller agent's proposal, so he offers still another proposal. At this, the seller's agent values the buyer's proposal below his expectation, while sending his next proposal.

<Table 6> Negotiation Results of 3rd Round

Round	Seller Agent			Buyer		
	Price	Due Date	MADM Result	Price	Due Date	MADM Result
1	4900	11	1.0	4900	10	0.9499372
2	4800	12	1.0	4800	11	0.95411867
3	4700	13	1.0	4700	12	0.9576548

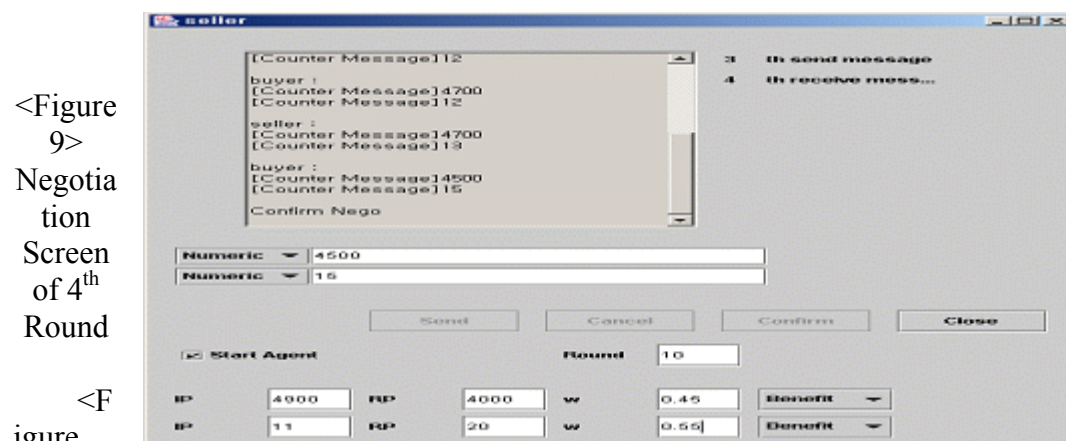


<Figure 8> Negotiation Screen of 3rd Round

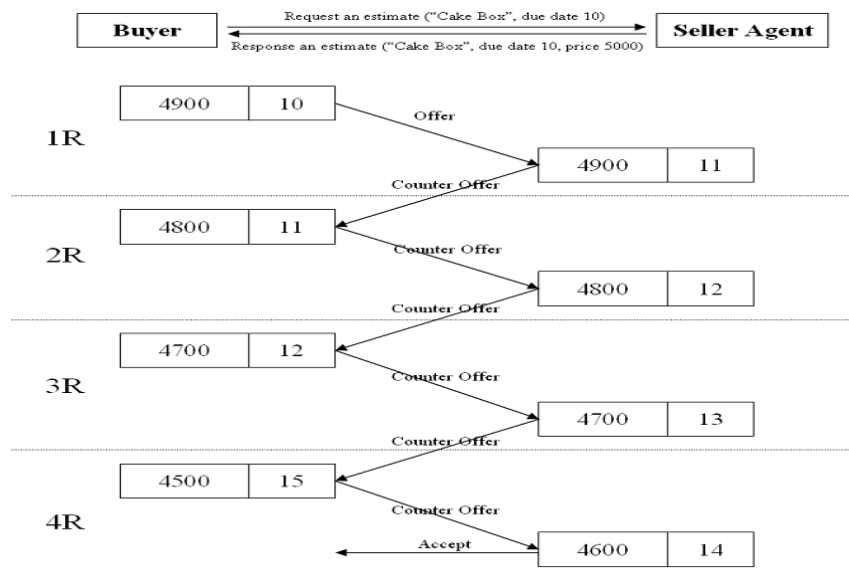
In the 4th round, the buyer is not satisfied with the seller agent's proposal – price: 4,700 and due date: 13. At this point in time, the buyer makes up his mind that he will extend the due date, instead lower the price. So he sends the new proposal – price: 4,500 and due date: 15. At last, the seller agent judges that the buyer's proposal is rated higher than his 4th round proposal – price: 4,600 and due date: 14. Accordingly, he accepts the buyer's proposal.

<Table 7> Negotiation Results of 4th Round

Round	Seller Agent			Buyer		
	Price	Due Date	MADM Result	Price	Due Date	MADM Result
1	4900	11	1.0	4900	10	0.9499372
2	4800	12	1.0	4800	11	0.95411867
3	4700	13	1.0	4700	12	0.9576548
4	4600	14	0.9633116	4500	15	0.9902245



<Figure 10> shows the whole process of negotiations between the seller agent and the buyer: request of estimate and its result, and the process of negotiations and their results.



<Figure 10> Seller's Agent and Buyer's Negotiation Process

Through this real case study, the validity of this MANS has been tested. It is regretful that this new system has not been compared with existing negotiation systems in terms of its features and strong points. However, as shown in the above case, MANS is able to evaluate and prepare negotiation proposals, and then proceed with negotiations without human intervention.

5. Conclusion

The process of negotiation is very sensitive to the change of environment and has lots of factors to be considered. Accordingly, many difficulties have followed this study. On the other hand, because of these difficulties, the development for negotiation system has not been activated until now. Also, most preceding studies on negotiation systems have focused on the negotiation support system. The automated negotiation systems such as Kasbah and Tete-a-Tete are also not fully supporting the process of automated negotiation.

This paper has tried to develop an automated negotiation system MANS, which performs automatically the function of organizing negotiation strategy, evaluating negotiation proposal, and creating negotiation proposal. In addition, this paper has applied the MANS to the real negotiations of an injection molding company to test its validity and efficiency. Consequently, this study has shown the potential to develop an automated negotiation system, while laying a foundation for the development of more advanced automated negotiation.

The theme for further studies ought to contain the creation of agent action-rule, which will support negotiations more practically by organizing flexible negotiation strategies in response to diverse negotiator's inclination.

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