Negotiating Mechanism of Manufacturing Enterprise Multi-Agent Supply Chain

Changhui Yang
School of Business, Zhengzhou University, P. R. China, 450001, yangchanghui@zzu.edu.cn

Abstract

In the multi-agent supply chain of manufacturing enterprise, there is the problem that purchasing agent need negotiate with supplier agent about price. Based on analyzing the multi-agent collaborative framework, this paper presents a price-negotiating model, and discusses the negotiating tactics and steps between purchasing agent and supplies agent. And then an example is discussed for validating the negotiating model. This model is useful to optimize the supply chain management of manufacturing enterprise. Manufacturing enterprise and strategic partnerships may share profit and achieve joint gains based on this model.

Keywords: Negotiating Mechanism, Multi-agent, Negotiating Tactics, Supply chain

1. Introduction

By means of multi-agent system to simulate, optimize and monitor the operating and managing of manufacturing enterprise in supply chain system has been a very important way in supply chain management researches [1]. In the multi-agent system of manufacturing enterprise supply chain, each agent represents different sector or department, organization or enterprise, which cooperates with each other and promptly accomplishes the course from raw material purchasing to product processing, assembling and distributing to the final clients or markets along the supply chain.

In recent years, there have been some researches on the multi-agent negotiation. Fatima et al studied negotiation between two parties of negotiation on price and utility based on Web [2]. And they set up a negotiation model and proposed the negotiation strategies of two good prices based on multi-agent system [3]. Jennings et al have discussed the negotiation model and strategy between both negotiating parties based on the multi-agent [4]. Sierra et al provided the calculating function of the negotiation fuzzy value, and verified the validity of the calculating function by empirical data [5]. Valverde et al mainly studied the computing method of the negotiation fuzzy value [6]. Gao et al focused on multi-stage model for the cooperation of the virtual enterprise and the self-study negotiation model based on Beyes distribution [7-9]. Carrascosa et al presented a flexible and efficient integration of high-level [10]. Lin et al studied the multi-agent negotiation mechanism to enhance the existing methods, and then evaluates the integrated systems performance through experimentation on the order fulfillment process in the context of Chinese metal industry [11]. Suh and Wen established the linkage between non-cooperative bargaining solutions [12]. Jiao et al developed an agent-based collaborative multi-contract negotiation system, which based on the distributed networked manufacturing paradigm to support multiple echelon negotiations within a dynamic supply chain [13]. Wanyama and Far presented an agent negotiation protocol that facilitates the solving of group-choice decision making problems [14]. Wang and Tadisina described a case study and built the simulation system based on a theoretical model and a real world case [15]. Kwon et al implemented MACE-SCM developed a framework based on multi-agent and case-based reasoning to facilitate collaboration and information sharing in the presence of high supply and demand uncertainties [16, 22]. Li created and described an Internet-based multi-agent prototype system to explore how the process of marketing strategy formulation can be improved by an Internet-enabled multi-agent intelligent system [17]. Wu et al proposed a class of evolving network models with physical position neighborhood connectivity and studied the clustering coefficients [18]. Yang studied multi-objective negotiating mechanism and tactic, and gave a multi-agent system of choosing supplier [19-23].

This paper will present a model of uni-objective negotiating mechanism in multi-agent supply chain system, in which the bilateral negotiation tactics between purchasing agent and supplies agent are also
proposed. This model will be useful to optimize the supply chain management of manufacturing enterprise.

2. Description of negotiation problem

The cooperation among the multi-agent is a key problem in the operating of the manufacturing enterprise supply chain, which can quickly respond to the operations. The multi-agent cooperation can be divided into 'cooperative agent' and 'non-cooperative agent' according to the type of agent cooperation. Usually, the cooperation among manufacturing enterprises in the internal of multi-agent supply chain is known as the cooperative agent, while the multi-cooperation among the external joints of the supply chain is always non-cooperative, because different agents have different benefit concerns. Cooperation among the strategy partners in supply chain is the main concern for the quick responding supply chain of the manufacturing enterprise. Here we mostly focus on the non-cooperation among multi-agents.

From the essence to say, cooperation is such a kind of course. Firstly, the purchasing agent of a manufacturing enterprise subcontracts some supplying tasks or some kinds of parts to supply agent, then the two cooperation parties come to an agreement to the price, quality, date of delivery and quota. Consequently, the supply agent finishes the task according to the contract and each party profit from it respectively. As both party’s target is to maximize its own profit or utility, the bilateral parties making a contract, in fact, is their gaming or bargaining. Based on the practical negotiations of the manufacturing enterprises in the quick responding supply chain, their gaming or bargaining can be divided into uni-objection negotiation among multi-agent and multi-objection negotiation among multi-agent. In this paper, we concern about uni-objection negotiation, that is, price negotiation mechanism among multi-agent for the manufacturing enterprises in the quick responding supply chain.

3. Muti-agent collaborative framework

The negotiation process will be finished based on the multi-agent collaboration. In order to realizing multi-agent collaboration, that need sharing ontology for transferring message between agents, agent communication language need KQML communication language, communication protocol can use the common TCP/IP protocol. And based on the contract net negotiation, multi-agent collaborative framework can be built just as figure 1 showing.

In the multi-agent collaborative framework based on contract net, that includes the manager, bidder, ANS (Agent Name Server) and Facilitator (intermediary agent).

As agent, the manager and tender of contract net compose task processor, knowledge base and contract processor. Task processor is responsible for handling and solving task, accepting the task form contract processor, and resolving task by means of local knowledge base and sending the results to contract processor. The local crunodes history knowledge, currently negotiating status and information of solving problem process have been stored in the knowledge base. Contract processor will verdict the mission, send bids and confirm the contract, analyze and explain arrived messages, and harmonize the total crunodes.

Agent name server (ANS: Agent Name Server) can maintain the agent registry table, and will realize the mapped from agent name to its physical address in the network. When one ANS starts, and will tell all the others agent and ANS in the network by broadcasting. Agent will decide whether use this ANS, other ANS will contact with this ANS and exchange the registry information and requesting message. Similarly, when agent enters the system, and send request to all the ANS by broadcasting, all the ANS will respond to the request, and then agent will decide the registering ANS by itself. An agent can inquire about one or more ANS that have known the results (that is the so-called client pull mode). An agent can inquire about only one ANS, and the ANS will find the way to inquire about the physical addressing of agent (that is the so-called server pull way). In addition, agent can also use the two ways to inquire about.

Intermediary agent (Facilitator) is responsible for managing the Yellow Pages of management system, build the mapped from agent functions to name in order to quickly find the right agent and interact with it. The handling capacity of ANS and Facilitator can be evaluated by two aspects including the quantity of handling request and the number of responding agent at the same time.
Finding agent from ANS is the overall service of system level, and finding agent from Facilitator is based on the ability of knowledge level.

Intermediary agent (Facilitator) is responsible for the management of the Yellow Pages, from the establishment of intelligent functions to the name of the mapping, in order to quickly find the right agent and interact with. ANS and the Facilitator of the handling capacity can adopt the following two aspects to evaluate: they deal with the request at the same time the number and the number of intelligent response. ANS find the agent system is the overall level of service, and the Facilitator to find agent is based on the ability to find the knowledge level.

When facing the purchasing mission, manufacturing agent will negotiate with suppliers’ agent A, B, C, and D. At first, manager is not to hurry to send bids, it will check its knowledge base, rationalize based on examples by means of the historical information. If there is the appropriate example, manager will send the purchasing request. Otherwise Manager send a message to the Facilitator for finding the agent of possessing this capability, Facilitator will return to the agent name list, and then Manager will request these ANS agent of the physical address, according to the returning results by ANS, Manager will negotiate with bidder. If the negotiations succeed, then the purchasing mission will be distributed.

4. Negotiation model, tactics and algorithm

4.1 Negotiation model and tactics

The price negotiation is the main part of the uni-objection negotiation based on multi-agent. Purchasing agent and supply agent make offer and bargain on the price, till they reach an agreement on the price both of their satisfying. This kind of negotiation among agents is very common among the manufacturing enterprises in the multi-agent supply chain system, such as the price negotiation of some parts between purchasing agent and supply agent.

In order to well explain this problem, we can describe it in this way: a manufacturing enterprise wants to purchase some kinds of parts, and some suppliers can provide these parts, so the purchasing agent of the manufacturing enterprise makes a negotiation on price with the supply agents. Their negotiation model and strategies will be discussed.

In order to describe this problem clearly, three assumptions are as follows:

Assumption 1: Individuals logos

As each agent want to achieve the maximum of its own utility, they refuse to accept the price below their expected, which price is called as a conflict point in the price negotiation. Let \((u_s, u_m)\) present as the final negotiation result, where \(u_s\) and \(u_m\) are shown as the supplier agent utility and manufacturing agent utility respectively. According to the above assumption, we will have \(u_s \geq c_s\), \(u_m \geq c_m\), where \(c_s\) and \(c_m\) are their conflict points respectively.
Assumption 2: Common logos
If there is the result $A_2$ that is more profitable for the two parties than the result $A_1$, then both of parties will not be satisfied with $A_1$.

Assumption 3: In the process of offer and counteroffer, the offer of the supply agent will be higher than purchasing agent’s, but their price will be agreed finally.

According to the above assumptions, we define price strategy of the two parties as follows:

The price strategy of the manufacturing enterprise is shown as formula (1).

$$P_{M}^{i} = P_{S}^{i-1} \left(1 + \alpha_{M} \left|P_{S}^{i-1} - P_{M}^{i-1}\right|\right) , i = 2, \cdots, n$$

(1)

In this formula, $\alpha_{M}$ is defined as the risk preference degree or the patience degree of the purchasing agent. Usually, the more risk-prone purchasing agent is, the larger $\alpha_{M}$ is, in other words, the larger patience degree of the purchasing agent is, the smaller $\alpha_{M}$ is. Especially, the price strategy of the manufacturing enterprise is $P_{M}^{i}$ when $i = 1$.

The price strategy of the supply agent is seen as formula (2).

$$P_{S}^{i} = P_{S}^{i-1} \left(1 - \alpha_{S} \left|P_{S}^{i-1} - P_{M}^{i-1}\right|\right) , i = 2, \cdots, n$$

(2)

In formula (2), $\alpha_{S}$ is defined as the risk preference degree or the degree of the patience of the supply agent. The more risk-prone supply agent is, the larger $\alpha_{S}$ is. In other words, the larger patience degree of the supply agent is, the smaller $\alpha_{S}$ is. Especially, the price strategy of the supply agent is $P_{S}^{i}$ when $i = 1$.

The ultimate goal of the price negotiation of the two parties is to achieve an agreement, where both utilities of purchasing agent and supply agent are maximization at the same time. We can define the joint function of price utility in two sides as follows.

$$U_{Union}^{i} = \frac{P_{S}^{i} - P_{M}^{i}}{P_{S}^{i} - P_{M}^{i}} \times \left(P^{*} - P_{M}^{i}\right)$$

(3)

In formula (3), $P^{*}$ is represented the ultimate price after bargaining between purchasing agent and supply agent.

According to the above discussions, it is assume that the supply agent wants to reach an agreement or an offer $P_{S}^{i}$, the purchasing agent proposes a counter-offer $P_{M}^{i}$. If the supply agent refuses this counter-offer, it has to make another new offer, until the two sides reach an agreement for a satisfying offer at same time.

Let $U_{S} \left(P_{S}^{i}\right)$ and $U_{S} \left(P_{M}^{i}\right)$ take as the supply agent earnings under the prices $P_{S}^{i}$ and $P_{M}^{i}$ respectively, then

$$U_{S} \left(P_{S}^{i}\right) = u_{S} (P_{S}^{i}) - c_{S} ; U_{M} \left(P_{M}^{i}\right) = u_{M} (P_{M}^{i}) - c_{M}$$

If the supply agent refuses a counter-offer $P_{M}^{i}$ of the purchasing agent and stick to its offer $P_{S}^{i}$, then the purchasing agent perhaps will refuse $P_{S}^{i}$. It will result in the end of this negotiation and the earnings of the two sides are zero at this situation.

However, the two sides do not want to get this result, both of whom not only want to reach an agreement, but also hope to loss little in the bilateral negotiation. In other words, they are in a dilemma to make choice in their negotiation.
If the probability that the purchasing agent would refuse the offer \( P^i \) of supply agent is defined as \( P \), then \( 1 - P \) is the probability which the purchasing agent would accept this offer \( P^i \) of supply agent. At the same time, the earnings of the purchasing agent are denoted by \( U^p (P^i, P^s) \).

At above situation, the rational decision-making behavior of supply agent is as follows: when \( U^s (P^i) > (1 - P) U^s (P^s) \),

\[
U^s (P^i) - U^s (P^s) < P
\]

That is, \( U^s (P^i) - U^s (P^s) \) is shown as the determination of the supply agent strived on his offer \( P^i \).

In the same reason, \( U^p (P^i) - U^p (P^s) \) is known as the determination of the purchasing agent strived on his counter-offer \( P^i \).

If one agent found that another agent determination strived on the agreement is greater than his, he would compromise in bilateral negotiation. If the determinations of the two sides are identical, both of them would compromise at the same time. They will continue to negotiate after compromised until Nash equilibrium point is obtained, that is to say, a unique rational solution \( (u^s, u^p) \) can be got in the bilateral negotiation.

At the same time, \( u^s \geq c_s, u^p \geq c_M \), and \( [u^s - c_s] \times [u^p - c_M] \) reaches to its maximum. The joint function of price utility in two sides \( U^{P^s} \) also reaches to the maximum.

If the agents are in the negotiation under the perfect information, which can know each other very well, a Nash equilibrium point will be quickly obtained in this negotiation. The time of communication and the expenses of negotiation between the two agents will be saved. Usually, it is an ideal situation that the internal multi-agents negotiate among the manufacturing enterprises in the supply chain, among of whom are close strategic partners in multi-agent system.

In the practice, the negotiation under the incomplete information is common among multi-agent negotiations. In such situation, the two parties should negotiate at many times so as to reach an agreement, which depends on the risk preference or patience of the two parties, namely \( \alpha^s \) and \( \alpha^p \) defined in the price strategy of both parties.

### 4.2 Algorithm steps of multi-agent

Based on the above discussion of the pricing strategy, the retaliating steps of multi-agent algorithm can be designed as following:

**Step 1:** For the certain purchasing mission, purchasing agent of manufacturing enterprise will send the request to supplier agent. Giving the first price of purchasing agent and supplier agent, purchasing agent will send the final negotiating number to supplier agent, denoting by \( t \).

**Step 2:** If \( P^i - P^s \leq |Q| \) (\( Q \), is the difference of both sides' price, and is the terminating condition of negotiation, is constant), the final price is \( (P^i + P^s)/2 \), and will turn to step 5. Otherwise, will continue negotiate, that is \( t = t + 1 \).

**Step 3:** If \( t > t_{\text{max}} \), purchasing agent will terminate the negotiation, and turn to step 6. Otherwise, purchasing agent will adopt its quoting strategy and renovate its quoting price, and will produce the counter-price.
Step 4: Supplier agent will respond the price of purchasing agent, and adopt its quoting strategy and renovate its quoting price, and will produce the counter-price, and turn to step 2.

Step 5: When purchasing agent terminates the negotiation with the entire suppliers agent, will compare all the negotiation results of suppliers agent, confirm the final supplier and endorse the contract with supplier, supplier will accept the mission.

Step 6: If this purchasing mission is not to succeed, purchasing agent will continue to negotiate with other supplier agent based on the above algorithm.

5. Example

Assuming that is a purchasing mission, purchasing agent of manufacturing enterprise will negotiate with supplier agent, giving the first price, purchasing agent and supplier agent will offer and court-offer by its offer-strategy, $\alpha$ is constant in the negotiation process, and negotiate according to the above steps. Table 1 is the finally negotiating results.

<table>
<thead>
<tr>
<th>$\alpha$</th>
<th>$P_{MA}$</th>
<th>$P_{PS}$</th>
<th>$P_{PC}$</th>
<th>$P_{SD}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>120</td>
<td>160</td>
<td>160</td>
<td>160</td>
</tr>
<tr>
<td>$Q=0.1$</td>
<td>$P_A$</td>
<td>146.65</td>
<td>140.00</td>
<td>136.01</td>
</tr>
<tr>
<td>t</td>
<td>17</td>
<td>12</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>$U$</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>$Q=0.01$</td>
<td>$P_A$</td>
<td>146.67</td>
<td>140.00</td>
<td>136.01</td>
</tr>
<tr>
<td>t</td>
<td>24</td>
<td>17</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>$U$</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. The Finally Negotiating Results

Analysis of results:

1. When the first offering-price of supplier is the same, negotiating numbers between purchasing agent and supplier agent is decided by $\alpha$, and the finally bargaining price is decided by $\alpha$. The bigger $\alpha$ is, the little negotiating numbers is, the lower the finally bargaining price is.

2. When suppliers’ $\alpha$ is the same, negotiating numbers between purchasing agent and supplier agent are decided by the first offering-price of supplier, and the finally bargaining price is decided by the first
offering-price of supplier. The higher the first offering-price of supplier is, the more the negotiating numbers are, and the higher the finally bargaining price is.

3. When the first offering-price and $\alpha$ of supplier is not the same, this situation is relatively complex. The negotiating numbers and the finally bargaining price of supplier are decided by $\alpha$ and the first offering-price.

6. Conclusion

The manufacturing enterprises in supply chain can be described as independent agents by the multi-agent technique. The agent can deal with related affairs by itself. The agents own characters assure the adaptability of the supply chain system. This paper provides the price negotiation model and implementing strategy among multi-agent of manufacturing enterprise in supply chain. According to the above discussions, the price negotiation strategies will let the competitions among the manufacturing enterprises in the multi-agent supply chain system become win-win, which will result to share their common profit in win-win way.

7. Acknowledgement

This work is supported by 10CGL004 and 10YJC630326.

8. References


