STUDY OF SUPPLY CHAIN MANAGEMENT BASED ON FUZZY ADAPTIVE AGENT

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ABSTRACT

Supply Chain Management is an important deal between suppliers and customers which lead to the customer negotiation of prices at varying rates. Designing an effective strategy for bidding customer orders is also an intricate problem due to intense competition in fast changing market environment. With increasing technological advancement the trade environment has become more sophisticated and so we have discussed about fuzzy logic in this paper, where it has developed SCM Trading agent in 2006 that have achieved good result.

I INTRODUCTION

A network of entities and their related activities are considered as a supply chain that work together to produce value for the customer. Supply Chain Management involves acquisition of raw materials, assembling of finished products, and delivering these products to customers. These activities are interrelated . It is crucial that such an activity is constantly monitored by manufacturers and reflected in their business strategies and the manufactures take into account the available inventory level and market demand in setting appropriate selling prices for assembled products. Therefore, two crucial tasks in supply chain management are the planning of raw material acquisition and competing for customer orders.

The agent bids for customer orders based on the spare factory cycle. In the 2003 and 2004 TAC SCM competitions, the majority of the agents adopted the two MRPs, make-to-plan and make-to-order as the main strategies. In the past decade, agent technology has been extensively used to model supply chain components. The generic properties of software agents such as autonomy, reactivity, pro-activeness and social ability are well suited to capture the characteristics of complex supply chain components and their interaction activities. The agent should be designed in such a way that it can exploit the advantages of both the strategies. Against this background, we have implemented a hybrid approach which includes both buy-to-build and buy-to-order strategies. In addition, the agebt deploys a fuzzy reasoning mechanism to control the target inventory level in order to adapt to market environment. Adjusting profit margin based on level of stock holding, market trend, rate of previous successful bidding price level of previous day is also capable by agent only.

One of the most successful applications of agent technology in simulating supply chain management is the annual Trading Competition in Supply Chain Management (TAC SCM). The Trading Agent Competition

(TAC) is an international forum designed to promote and encourage high quality research into the trading agent problem.

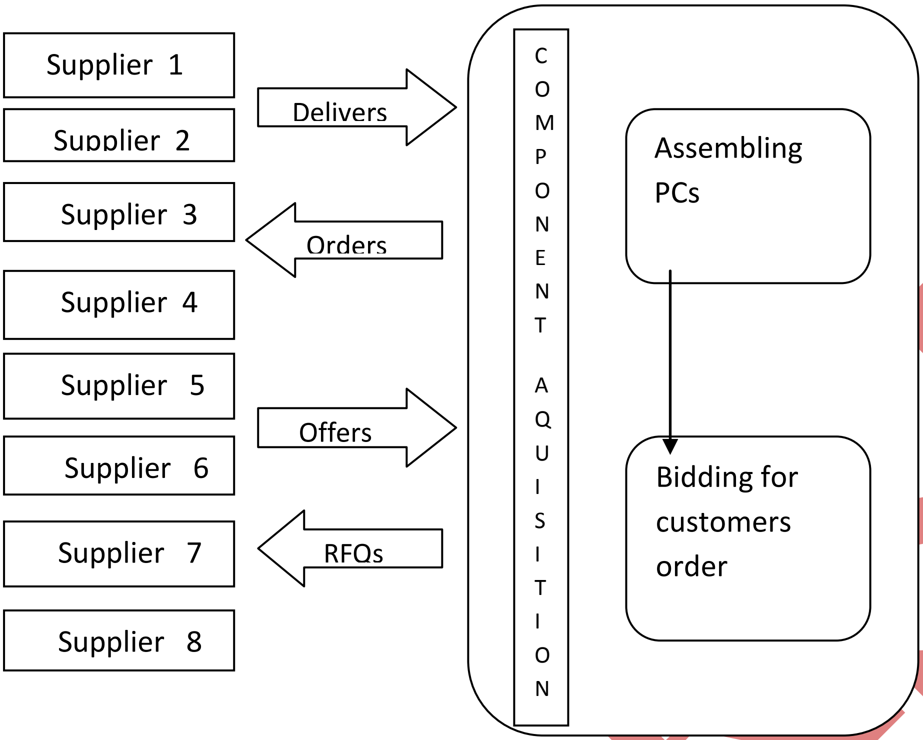
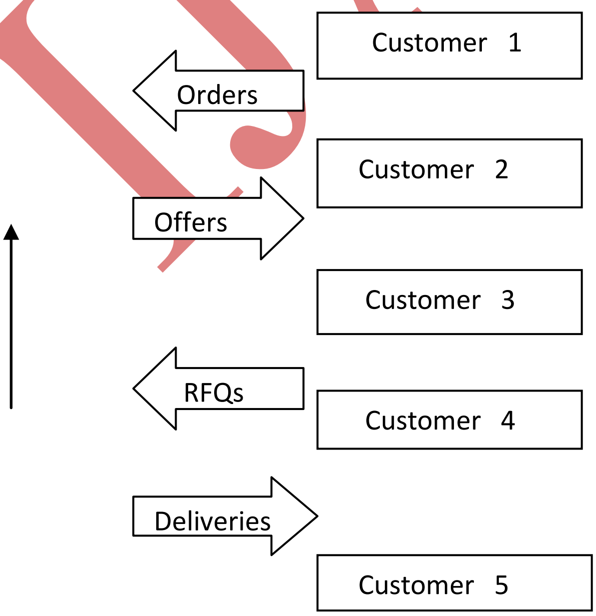


Fig 1: TAC SCM scenario

II GAME OVERVIEW

In TAC SCM, six agents compete in each game. This game is continued for 220 simulated days. To maintain their inventory level to build and sell different types of PCs, agents compete in two markets (supplier side and customer side). 16 PCs are built from four components: CPUs, motherboards, memories and hard drives



Each PC type is defined with its constituent components, the number of assembly cycles required and market segment they belong to. Each component type has two suppliers from computer hardware manufacturing industries. Here we take number of suppliers as eight and undefined customers , and they are treated as single entity

III FUZZY BASED AGENT

In this the agent has used fuzzy logic reasoning to control target PCs inventory level and price adjusting for customer order bidding.

3.1 Target inventory level

First Day - Offers are being send to the agents for suppliers that are based on the available capacity, which is considered as the early stage of the game. In the beginning all suppliers have full capacity and therefore the price of components may be lower than average on first day. Bulk RFQs are sent by many agents at first day and as a result it can increase the offering price. The agent sends RFQs for the components which are to be delivered in first three weeks of the game.

Table 1.

Components	Delivery Date				
	Day 3	Day 6	Day 9	Day 18	Day 25
X CPU,2.0GHz	250	250	400	300	400
X CPU,5.0GHz	250	250	400	300	400
Y CPU,2.0GHz	250	250	400	300	400
Y CPU,5.0GHz	250	250	400	300	400
X Mother-board	500	500	800	600	800
Y Mother-board	500	500	800	600	800
Memory,1GB	500	500	800	600	800
Memory,2GB	500	500	800	600	800
Hard disk, 300GB	500	500	800	600	800
Hard disk, 500GB	500	500	800	600	800

Day 2 to Day 210 – the UMTac-06 agent uses fuzzy logic to control the inventory level of PCs. The fuzzy reasoning is based on the market trend and previous sale result. First we calculate the average daily customer demand which is the average number of PCs requested by customers in their RFQs which are sent to all agents in the competition in the last five days period. Since the UMTac-06 agent may not win all the RFQs, We define the basic daily PC demand as 1/5 of the average daily customer demand. Next, we use the basic daily PC demand as the inventory level and adjusted with the fuzzy logic to adapt to the market environment. The fuzzy rules take into accounts two inputs: profit margin and market trend.

Fuzzy input 1, profit margin of each type of PC: Revenue can be directly affected by profit margin. Priorities are given to PCs having higher profit margins according to UMTac-06 agent. We then calculate average cost of each type of components by recording the components which agent has ordered. The profit margin is equal to profit of that type of PC divided by average cost. Based on profit margin, we define fuzzy set of values as depicted in figure 2.

Fuzzy input 2, market trend of each type of PC : For calculating the market trend we use Simple Moving Average (SMA). It is used for forecasting the increase or decrease the demand of PC. The UMTac-06 agent calculates the market trend by dividing the five days SMA with 10 days SMA. The fuzzy set for market trend are depicted in figure 3.

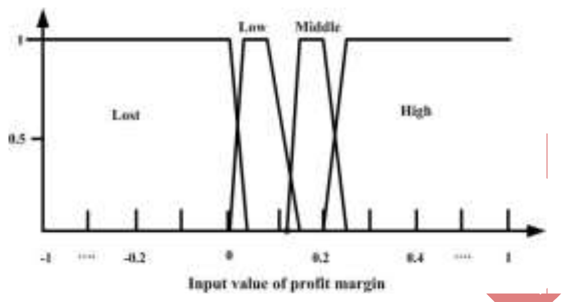


Figure 2. Fuzzy Set of Profit Margin of Each Type of PC

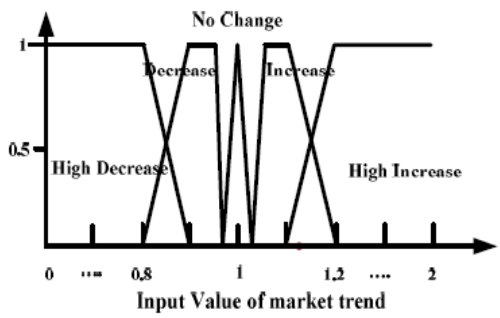


Figure 3. Fuzzy sets of market trend for each type of PC

Fuzzy output, adjusting target inventory level of each type of PC: We define the fuzzy output as a percentage value which will be added to the basic daily PC demand from step one. We define the fuzzy set value in Table 2 and corresponding fuzzy rules in Table 3.

Table 2: The fuzzy set value of target inventory level

Cut	Reduce more	Reduce	Keep	Add	Add more
	-40%	-22%		5%	20%
-90%	-40%	-18%	-4%	8%	25%
-90%	-25%	-8%	0	20%	40%
-90%	-20%	-5%	0.4%	22%	40%

Based on these fuzzy variables, 20 rules can be generated from all possible combination of fuzzy input and output. Examples of generated fuzzy rules are given in Table 3.
Profit Margin (P) Î{*lost, low, middle, high*}

Market Trend (MT) Î{*high decrease, decrease, no change, increase, high increase*}

Adjusting Target Inventory Level (T) Î{*cut, reduce more, reduce, keep, add, add more*}

Critical stage

In this stage there will be a shortage of components in a short time. To eliminate this problem, the agent will order the components which are to be delivered within a short lead of time. The agent is considered to be in the critical stage if the estimated component holding for the next five days is less than 4μ. The value of μ fluctuates every day. Let *Vi* be the current inventory level at day *i* and *ECAi* be the expected component arrival at day *i*. For instance, in Table 4 , Vi+ ΣECAi<6μ means that the components which are supposed to be delivered within 9 days plus the current inventory level must be less than 6μ.

IF P is lost and MT is decrease THEN T is cut.
IF P is lost and MT is increase THEN T is reduce.
IF P is low and MT is decrease THEN T is reduce.
IF P is low and MT is increase THEN T is keep.
IF P is middle and MT is decrease THEN T is keep.
IF P is middle and MT is increase THEN T is add.
IF P is high and MT is decrease THEN T is keep.
IF P is high and MT is increase THEN T is add more

Table 3: The Rule Set For Target Inventory Level

RFQ number	Order Amount	Delivery Date	Constraint Rule
1	μ	i+5	$V_i+\sum_{i+1}^{i+9} ECAi < 6\mu$
2	μ	i+10	$V_i+\sum_{i+1}^{i+12} ECAi < 10\mu$
3	2μ	i+15	$V_i+\sum_{i+1}^{i+18} ECAi < 15\mu$
4	2μ	i+20	$V_i+\sum_{i+1}^{i+24} ECAi < 18\mu$

Table 4. The Number of Components to Be Ordered For Critical Stage

Shortage stage

This stage is used to indicate that there will be a potential shortage of components in coming few days. In inventory the sum of the number of current components and the components which is delivered within 9 days is less than 6 day demand requirement (6μ), we define it as a shortage stage as shown in table 5

RFQ number	Order Amount	Delivery Date	Constraint Rule
1	2μ	i+10	$V_i+\sum_{i+1}^{i+12} ECAi < 11\mu$
2	2μ	i+15	$V_i+\sum_{i+1}^{i+18} ECAi < 15\mu$
3	2μ	i+20	$V_i+\sum_{i+1}^{i+24} ECAi < 19\mu$
4	μ	i+25	$V_i+\sum_{i+1}^{i+30} ECAi < 25\mu$

Table 5. The Number of Components to Be Ordered For Shortage Stage

Normal stage

If the sum of the number of current components in inventory and the components which is going to be delivered within 14 days is less than 10 day demand requirement (10**μ**), we define it as a normal stage as shown in table 6

RFQ number	Order Amount	Delivery Date	Constraint Rule
1	2μ	i+15	$Vi+\sum_{i+1}^{i+20} ECAi < 14\mu$
2	μ	i+20	$Vi+\sum_{i+1}^{i+26} ECAi < 18\mu$
3	μ	i+25	$Vi+\sum_{i+1}^{i+30} ECAi < 21\mu$
4	μ	i+35	$Vi+\sum_{i+1}^{i+40} ECAi < 28\mu$

Table 6. The number of components to be ordered for normal stage

Maximum stage

We define this stage as, the current inventory level is sufficient for a relatively long period. If the agent will order for future usage a small quantity, there is likely to be a shortage in long term as shown in table 7.

RFQ number	Order Amount	Delivery Date	Constraint Rule
1	2μ	i+20	$V_{i+}\sum_{i+1}^{i+20} ECAi < 24\mu$
2	μ	i+25	$V_{i+}\sum_{i+1}^{i+26} ECAi < 18\mu$
3	1/2μ	i+30	$V_{i+}\sum_{i+1}^{i+35} ECAi < 22\mu$
4	1/2μ	i+35	$V_{i+}\sum_{i+1}^{i+40} ECAi < 26\mu$

Table 7. The number of components to be ordered for maximum stage

Day 210 to 220: To reduce the unused components at the end of competition, UMTac- 06 stops ordering from suppliers after day 210.

3.2 Bidding for Customer Price

It tries solves two major problems:

Selection of customer RFQs : Based on four criteria, the agent select RFQs:

- *Due date*: It varies from 3-12 days. Higher priorities are assigned to shorter due date as we predict that other agents may not have enough PCs, we define priority P_D based on delivery date :

  $P_D(x) = 1000-100(x-3)$, where x is required delivery date and $12 \geq x \geq 3$

- *Reserve price*: It imposes high reserve price to higher priorities RFQs. The reserve price is between 75% and 125% of a normal price of a PC. We define priority P_R for reserve price :

  $P_R(x) = 25(x-75) + 25$, where x is the reserve price and $125 \geq x \geq 75$

- *The number of units:* It is requested by customer RFQ. Production capacity is limited of all the agents. Therefore the number of units requested in RFQ is low, the agent can bid more RFQs and in turn it increases the chance of more customer orders. Also, the penalty is likely to be low if the agent cannot fulfil the RFQ. For different number of units we define the priority P_U as follows:

  $P_U(x) = 2000-100(x-1)$, Where x is number of requested units in RFQ and $20 \geq x \geq 1$

- *Penalty*: RFQs with lower penalty is assigned higher priority by the agent. The customer RFQ ranges between 5% to 15% for a customer reserve price per day. We define priority P_N as follows:

  $P_N(x) = 50(x-5) + 50$,

  Where x is the penalty and $15 \geq x \geq 5$

After receiving all RFQs from customer the agent defines priority of each RFQ as :

$$Priority = P_D + P_R + P_U + P_N$$

Bidding Price Setting

Based on the priority, the agent selects RFQs and the profit level is adjusted based on the number of available PCs in the stock, the market trend, bidding price of previous day and recorded success rate.

Fuzzy output, price adjustment: The price adjustment is the output of fuzzy logic reasoning which is to be applied to the bidding price of previous day. The fuzzy set for price adjustment is given in Table 8.

Reduce More	-17%, -16%, -12%, -11%
Reduce Little	-12%, -11%, -8%, -7%
Reduce	-8%, -7%, -3%, -2%
Keep	-2%, 0%, 2%
Add	2%, 3%, 7%, 8%
Add Little	7%, 8%, 11%, 12%
Add More	11%, 12%, 16%, 17%

Table 8. The Fuzzy Set of Price Adjustment

Based on the fuzzy variables, 375 rules can be generated. 162 fuzzy rules are obtained after simplification. From the simplified set only example of five rules are taken due to limited space, it is given in Table 9.

	1.	2.	3.	4.	5.
PCs in stock	Very low	Very low	Very low	Very high	Very high
Market Trend	Any	Any	Any	Any	Any
Success rate	Very low	Very low	Very low	Very low	Very low
Bidding price of previous day	Very low	low	Nor-mal	High	Very High
Price adjust-ment	Keep	Keep	Keep	Keep	Keep

Table 9: The First Five Rules after Simplification.

From table 9 the Rule 1 states that the agent should wait for better market situation if the success rate for customer order bidding price, bidding price of previous day and PCs stock leve is very low; the price adjustment should be set to "keep".

3.3 Assembling PCs

Fulfilling customer order is a crucial job for agent and higher priorities are given to outstanding order. The agent assembles PCs based on the target inventory order. The agent calculates the difference between target inventory level and current stock level. The factory will assemble only additional PCs for the inventory using free capacity, it will assemble upto 4 days requirement (4µ) as inventory.

Without delay the PCs are delivered to the customer if there are sufficient numbers of units in the inventory. Otherwise, the agent waits until all units are assembeled by the inventory.

3.4 Agent for Final Rounds

For the final round of TAC SCM competition, we have revised the fuzzy logic-based agent with some additional heuristic rules.

Bidding price for customer RFQs*:* In the previous round, the agent only selects a RFQ if its reserve price is higher than calculated bidding price. The customer RFQs is scanned three times by the agent. In first round, the agent uses bidding price calculated from fuzzy logic based price adjustment to select RFQ. In second round, the remaining RFQ is scanned by the agent using 2% bidding price. In third round, it repeats the second round using 4% reduced bidding price.

Ordering component: To control the target PCs inventory level agent uses fuzzy logic. The agent should acquire more components if it can sell a large number of PCs.

Reserve price for components**:** Without gaining profit the agent will not sell any PC. Therefore the agent sets the reserve price for components ordering based on profit margin of the PC's component. For calculating reserve price, profit margin is added to average price of the component.

Balancing stock level of component: Four types of component are required by agent to assemble a PC. Every component is essential, unavailability of any one type of component leads to difficulty in assembling of that particular type of PC. In both seeding and final rounds, the agent is designed not to order any component after day 210 to avoid component build up. After 210 day there is a shortage of one component, the agent then send RFQ to the supplier and will try to increase the stock level of that particular component. We maximize average component inventory as 920 units which is maximum capacity of remaining 10 days.

IV SUMMARY

In this paper, we describe a fuzzy logic based supply chain management agent which is capable of adapting to the market situation by controlling the target inventory level and profit margin. The agent look over stock holding, market trend, rate of previous successful bidding and bidding price of previous days. It uses to buy and build to order strategies.

In buy to buy strategy, agent maintains a safe inventory level which when falls below safe level, is negotiated with suppliers and sources the required components. In build to order strategy, agent requires components after it has secured customer's order. So fuzzy logic proves to be better from other logic in factory utilization, storage, bank interest and penalty. Still, we are investigating the possibility of selecting customer RFQs based on multi objectives optimization techniques.

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