A Cooperation Mechanism among Seller Agents based on Exchanging Goods in Agent-mediated Electronic Commerce

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Abstract

Agent-mediated electronic markets have been a growing area of agent research and development in recent year. There exist a lot of e-commerce sites on the Internet (e.g. Priceline.com, Amazon.com, etc.). These e-commerce sites have proposed new business models for effective and efficient commerce activity. Intelligent agents have been studied very widely in the field of artificial intelligence. For purpose of this paper, an agent can act autonomously and collaboratively in a network environment on behalf of its users. It is hard for people to effectively and efficiently monitor, buy, and sell at multiple e-commerce sites. If we introduce agent technologies into e-commerce systems, we can expect to further enhance the intelligence of their support. In this paper, we propose a new cooperation mechanism among seller agents based on exchanging their goods in our agent-mediated electronic market system, G-Commerce. On G-Commerce, seller agents and buyer agents negotiate with each other. In our model, seller agents cooperatively negotiate in order to effectively sell goods in stock. Buyer agents cooperatively form coalitions in order to buy goods based on discount prices. Seller agent's negotiation is realized on an exchanging mechanism among selling goods. Our current experiments show that exchanging mechanism enables seller agents to effectively sell goods in stock. Also, we present the Pareto optimality of our exchanging mechanism.

keywords: Agent-mediated electronic commerce, Cooperation among agents, Seller cooperation mechanisms, and Exchanging mechanisms

1 Introduction

Over last few years, the number of electronic commerce (e-commerce) sites has been increased tremendously. These e-commerce sites have proposed new economic models for effective and efficient commerce. In the field of artificial intelligence and multiagent systems[18], intelligent agents have been studied very widely. An agent can autonomously and collaboratively act on behalf of its users on the Internet. It is tedious tasks for people to monitor, buy, and sell at multiple e-commerce sites. If we can apply agents technologies into e-commerce systems, we can expect to further enhance the intelligence of their support.

There have been several researches on agent-mediated electronic commerce[7]. We can classify these researches into two categories. One category is agent-based electronic markets (e.g. Kasbah[3], Tete-A-Tete[8], FishMarket[16], eMediator[17], AucutionBot[20], etc.). The other is shopping information gathering agents[1][5][6][10][11]. The details of the related work is described in section 5. In this paper, we focus on the agent-based electronic markets. On an electronic market, there exist several agents. Agents try to sell or buy goods on behalf of their user. The main advantage of agent-based electronic markets is that agents can reduce user's work load for selecting, monitoring, and negotiating. Suppose an user wants to sell an item (e.g. a computer). If this user employs a seller agent on an electronic market, he does not need to find several buyers, select one buyer, and negotiate with that buyer. His agent can automatically find several buyer agents, select the best buyer agent, and negotiate with the best buyer agent on behalf of him.

E-commerce sites that can handle volume discount (e.g. Volumebuy.com) have been developed very widely. In these sites, buyers can advantageously negotiate with sellers and purchase goods at volume discount prices by forming a buyer coalition. In this paper, we propose a new agent-mediated electronic commerce scheme based on volume discount. We have develop an electronic market based on volume discount. In this system, buyer agents can effectively make coalition and can purchase items at the volume discount price[12]. Yamamoto and Sycara[21] has also proposed a volume discount scheme (called the GroupBuyAuction scheme) for coalition formation among buyer agents on an agent-based electronic markets.

If a seller agent does not have enough number of an item, he misses an opportunity to sell the item. Buyers also miss an opportunity to purchase the item. Namely, if a seller agent does not have enough number of an item, the overall utility for negotiation must be decreased. In the real world, a seller can try to find another seller agent that has extra items in its stock. Then, they try to exchange so that they can sell enough items for buyers. In our electronic market system, *G-Commerce*(a group-based **e-commerce** support system), we propose a cooperation mechanism among seller agents based on exchanging items in their stock. We have proposed an exchanging protocol among agents[9]. In the previous work[9], we apply the exchanging protocol to a meeting scheduling problem. In this paper, we modify the exchanging protocol, and apply it as a cooperation mechanism among seller agents on *G-Commerce*.

The rest of this paper consists of the following five sections. In Section 2, we present the outline of an agent-based e-commerce system, *G-Commerce*. Also, we formalize an agent-mediated market system based on volume discount. In Section 3, we propose a new exchanging mechanism among seller agents. In Section 4, we discuss the Pareto optimality of our exchanging mechanism, and the result of our current experiments. In section 5, we compare our approach with the other approaches. We describe several concluding remarks in Section 6.

2 *G-Commerce*: An Agent-mediated Electronic Market

2.1 Outline of *G-Commerce*

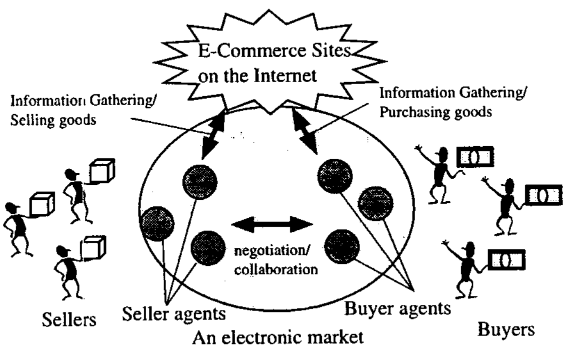

Figure 1. Outline of *G-Commerce*

Figure1 shows the outline of our electronic market system, *G-Commerce*. In the system, there exist one electronic market that is a computer on which agents act cooperatively and autonomously. A seller (human) can create a seller agent that can automatically find buyer agents and negotiate with buyer agents. A buyer (human) can create a buyer agent that can automatically find seller agents and negotiate with seller agents. These agents can also access World Wide Web sites and sell/purchase goods on the Internet.

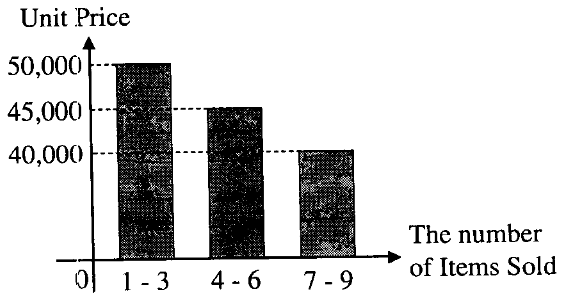

Figure 2. An Example of Seller's Price Table

In *G-Commerce*, a seller agent can sell multiple items. Each item has a price table, a deadline, and the number of the same items in stock. A price table represents item's discount rate for the number of buyers. Figure 2 shows an example of a price table. According to this example, if buyer agents purchase 5 items, the unit price becomes 45,000 yen. The deadline represents the date at which the item must be sold.

2.2 A Negotiation Scheme on *G-Commerce*

G-Commerce is a kind of reverse commerce system (e.g. Priceline.com) where buyer agents can pool their demands, and seller agents offer discount prices to sell large volumes of products at once. We define terms and notations.

Buyer agents: $B = \{b_1, b_2, \ldots, b_l\}$ denotes a set of buyer agents.

Seller agents: $S = \{s_1, s_2, \ldots, s_m\}$ denotes a set of seller agents.

Items: $G = \{g_1, g_2, \ldots, g_n\}$ is a set of items.

Seller's items: $G(s_j) = \{g(s_j)_1, g(s_j)_2, \ldots, g(s_j)_n\}$ is a set of seller s_j's items. A seller can sell several kinds of item.

Buyer's desired item: $g(b_k)$ is a buyer b_k's desired items.

Price table: s_j's price table of g_i is represented as a function $p(s_j, g_i) : N \rightarrow R$. N and R are the set of natural number and real number, respectively. $p_n(s_j, g_i)$ is a unit price when n of g_i are sold together. n denotes the number of g_i.

Cost of items: $cost(s_j, g_i)$ denotes s_j's cost for purchasing or producing item g_i.

Reservation price: $r(b_k, g_i)$ represents buyer agent b_k's reservation price for g_i.

Seller's number of items: $num(s_j, g_i)$ denotes the number of item g_i sold by s_j.

Buyer's desired number of items: $num(b_k, g_i)$ denotes buyer agent b_k's desired number of g_i.

A Coalition: $C(g_i) \subset B$ denotes a buyer coalition to purchase g_i.

Coalition's desired number of items: $num(C(g_i)) = \sum_{b_k \in C(g_i)} num(b_k, g_i)$ denotes coalition $C(g_i)$'s desired number of item g_i.

Buyer's utility: When buyer agent b_k bought g_i from s_j, his utility can be defined as $u_{b_k}(g_i) = r(b_k, g_i) \cdot num(b_k, g_i) - p_{num(b_k, g_i)}(s_j, g_i) \cdot num(b_k, g_i)$.

Buyer coalition's utility: Coalition $C(g_i)$'s utility can be defined as $u_{C(g_i)}(g_i) = \sum_{b_k \in C(g_i)} r(b_k, g_i) \cdot num(b_k, g_i) - p_{num(C(g_i))}(s_j, g_i) \cdot num(C(g_i))$

In *G-Commerce*, agents negotiate with each other according to the following steps. The basic idea is that firstly buyer agents try to buy items directly from seller agents. If they fail, the seller agents try to exchange their items so that they have enough items to sell in their stock.

(Step 1): Buyer agents arrive at *G-Commerce*. Each buyer agent declares its demand. The demand of the buyer agent b_k consists of his reservation price $r(b_k, g_i)$ and his desired number of items $num(b_k, g_i)$. Buyer agents who are trying to purchase the same item g_i form the coalition C_i.

(Step 2): When the seller agent s_j arrives at our market, if there are coalitions $C(g_i)$ and $g_i \in G(s_j)$, he tries to sell the item g_i. If not, he tries to wait a buyer who wants to purchase his items $G(s_j)$ until the deadline given by an user.

(Step 3): If $num(s_j, g_i) \geq \sum_{b_k \in C(g_i)} num(b_k, g_i)$, then seller s_j succeeds to sell item g_i to coalition $C(g_i)$, and this negotiation finishes. If $num(s_j, g_i) < \sum_{b_k \in C(g_i)} num(b_k, g_i)$, then go to (Step 4).

(Step 4): In this step, in order to satisfy buyers' demand, seller agent s_j tries to increase the number of the item g_i by using our exchanging mechanism proposed here. For example, the seller agent s_j can get more the item g_is from another seller agent s_k. In exchange for the item g_is, the seller agent s_j give another item g_l to the seller agent s_k. The details of the exchanging mechanism is shown in Section 3.

Firstly, the seller agent s_j tries to find a seller agent who waiting to exchange the item g_i. If there is a such agent, the seller agent s_j tries to exchange items. When there are a lot of agents who can exchange items, he tries to find most reasonable deal. Secondly, if there is no agent who waits to exchange items, the seller agent s_j tries to wait that another seller agent will arrive at this market until the deadline given by an user.

3 An Exchanging Mechanism among Seller Agents

In the Step 4 in Section 2.2, if a seller agent does not have enough items, he tries wait another seller agent who can exchange the items. Then, if they can succeed to exchange their items, both of seller agents can increase their utility. Also, even buyer agents can get more revenue because of a lot of discount based on a large number of items. Here, we propose a cooperation

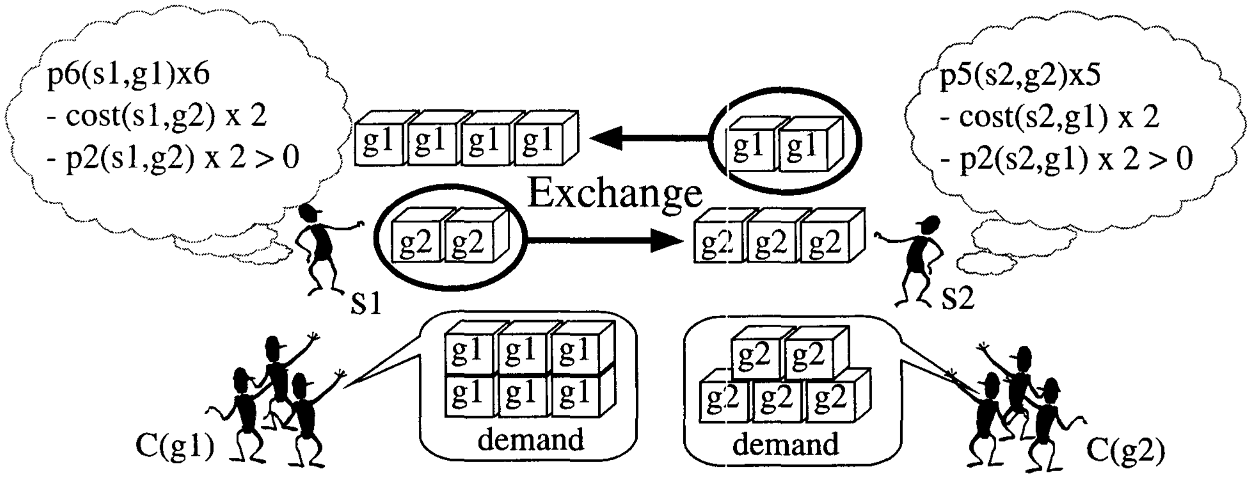

Figure 3. An exchanging mechanism between two seller agents

mechanism among seller agents based on exchanging their items.

Figure 3 shows an example of exchanging items. There exist two seller agents, s_1 and s_2. The seller agent s_1 has four item g_1s and two g_2s. The seller agent s_2 has two item g_1s and three item g_2s. Suppose that a buyer coalition $C(g_1)$ tries to purchase six g_1s from the seller agent s_1. Also, another buyer coalition $C(g_2)$ tries to purchase five g_2s from the seller agent s_2. Since the seller agent s_1 does not have enough item g_1s, he tries to negotiate with the seller agent s_2. Firstly, the seller agent s_1 proposes that he gives two item g_2s to the seller agent s_2 in exchange for that s_2 gives him two item g_1s. Here, if $p_6(s_1, g_1) \times 6 - cost(s_1, g_2) - p_2(s_1, g_2) \times 2 > 0$ for s_1, and $p_5(s_2, g_2) \times 5 - cost(s_2, g_1) - p_2(s_2, g_1) \times 2 > 0$ for s_2, we define that both of the seller agents, s_1 and s_2, can agree this proposal. Since both of the seller agents can make profit, they can exchange items. We define a criterion for exchanging items as follows:

Definition 1 (A Criterion for Exchanging Items) *Suppose, there exist two seller agents, s_1 and s_2, and two kinds of item, g_1 and g_2.*

(case 1) *In the case that $shortage(s_1, g_1) = num(C(g_1)) - num(s_1, g_1) > 0$ and $shortage(s_2, g_2) = num(C(g_2)) - num(s_2, g_2) > 0$, if s_1's utility $u(s_1) = p_{num(C(g_1))}(s_1, g_1) \times num(C(g_1)) - cost(s_2, g_2) \times shortage(s_2, g_2) - p_{shortage(s_2,g_2)}(s_1, g_2) \times shortage(s_2, g_2) > 0$, and s_2's utility $u(s_2) = p_{num(C(g_2))}(s_2, g_2) \times num(C(g_2)) - cost(s_1, g_1) \times shortage(s_1, g_1) - p_{shortage(s_1,g_1)}(s_2, g_1) \times shortage(s_1, g_1) > 0$, these agents can reach an agreement since both of them can get positive utility.*

(case 2) *In the case that $shortage(s_1, g_2) = num(C(g_2)) - num(s_1, g_2) > 0$, and $shortage(s_2, g_1) = num(C(g_1)) - num(s_2, g_1) > 0$, if s_1's utility $u(s_1) = p_{num(C(g_2))}(s_1, g_2) \times num(C(g_2)) - cost(s_2, g_1) \times shortage(s_2, g_1) - p_{shortage(s_2,g_1)}(s_1, g_1) \times shortage(s_2, g_1) > 0$, and s_2's utility $u(s_2) = p_{num(C(g_1))}(s_2, g_1) \times num(C(g_1)) - cost(s_2, g_2) \times shortage(s_1, g_2) - p_{shortage(s_1,g_2)}(s_2, g_2) \times shortage(s_1, g_2) > 0$, these agents can also reach an agreement since both of them can get positive utility.*

4 Discussion

4.1 Pareto Optimality of Our Exchanging Mechanism

Our exchanging mechanism is one of the rules in bargaining problems in the game theory[15]. In a bargaining problem, if an outcome $(u(s_1), u(s_2))$ satisfies the following (1), (2), and (3) conditions, we can say the outcome is *Pareto optimal.*

1. $u(s_1) \geq u(s_1)^*$ and $u(s_2) \geq u(s_2)^*$. Here, $u(s_1)^*$ and $u(s_2)^*$ mean the current status. Essentially, this means $u(s_1)$ and $u(s_2)$ maximize the utilities.
2. $(u(s_1), u(s_2))$ is a point of R. R denotes the set of all possible points.

3. There is no $(u(s_1), u(s_2))$ in R, different from $(u(s_1)', u(s_2)')$, such that $u(s_1) \geq u(s_1)'$ and $u(s_2) \geq u(s_2)'$

In our exchanging mechanism, agents have two strategies. One is to try to exchange. The other is to do nothing. Thus, two strategies are called *str. 1* and *str. 2*. Obviously, when agents can get an agreement by exchanging, the utilities, $u(s_1)$ and $u(s_2)$ maximize their utilities. This satisfies the condition (1). Also, in our exchanging mechanism, the set of all possible strategies is $\{(str.1, str.1), (str.1, str.2), (str.2, str.1), (str.2, str.2)\}$. Here $(str.1, str.2)$ means s_1's strategy and s_2's strategy are str. 1 and str. 2, respectively. The set of all possible utilities is $\{(u(s_1), u(s_2)), (0,0), (0,0), (0,0)\}$. $(u(s_1), u(s_2))$ is the utilities that results from $(str.1, str.1)$. Obviously $(u(s_1), u(s_2))$ is a point of R. This satisfies the condition (2). In terms of the condition (3), agents can get positive utilities only when they use the $(str.1, str.1)$. When they use other strategies their utilities are $(0,0)$. This means the condition 3 is satisfied. Therefore, we can say an outcome by using our exchanging mechanism satisfies the *Pareto optimality*.

4.2 Experimental Results

In order to show how effectively the exchanging mechanism we proposed can work, we conducted several experiments in the following setting.

- Number of sellers: 5
- Number of buyers: 500
- Prices of an item: 200 to 300
- Number of kinds of items: 10
- Seller's maximum number of items: 10
- Distribution for buyer's desired item: Normal distribution
- Distribution for seller's utility for an item: Uniform distribution
- Distribution for seller's number of items: Uniform distribution

The traditional method consists of (Step 1) to (Step 3). Our method method consists of (Step 1) to (Step 4). Essentially, the traditional method does not use the exchanging mechanism we proposed here. We tried varying the parameters in order to make comparisons between several settings. 1 setting consists of 1000 trials. 1 trial consists of 1000 intervals. 1 interval consists of one cycle of the traditional method or our method. Buyer agents and seller agents arrive at this electronic market every n intervals. n is an inversely proportional number to the number of agents.

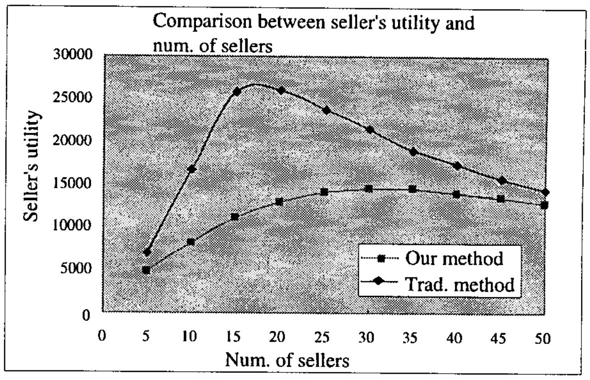

Figure 4. Comparison between seller's utility and number of sellers

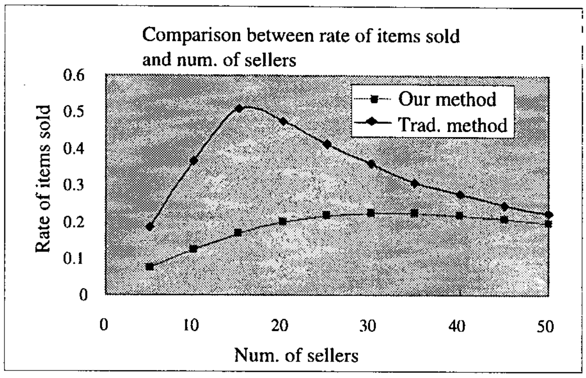

Figure 5. Comparison between rate of items sold and number of sellers

The followings show results of our experiments. Figure 4 shows comparison between seller's utility and number of sellers. Figure 5 shows comparison between rate of items sold and number of sellers. As these graphs indicate, our method can gain more utilities and the rate of items sold than the traditional method. In particular, if the number of sellers is within 10 to 25, our method can gain about twice utilities that the traditional method can gain. In terms of of the rate of items sold, our method can gain it about three to five times as much as that the traditional method can

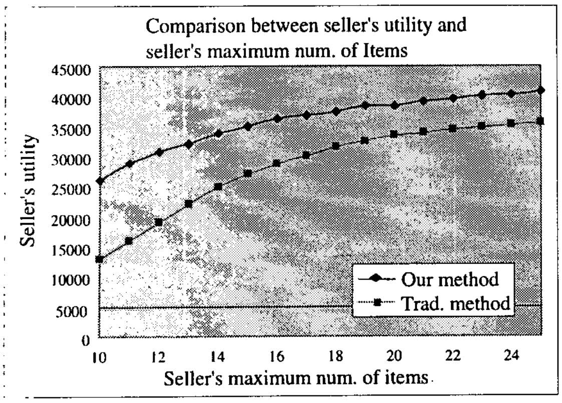

Figure 6. Comparison between seller's utility and seller's maximum number of items

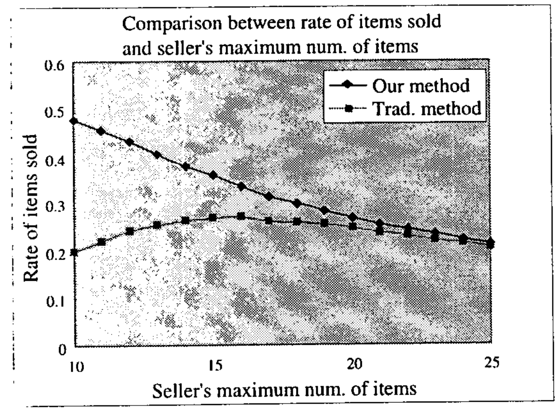

Figure 7. Comparison between rate of items sold and seller's maximum number of items

gain. The reason why the seller's utility and the rate of items sold is low when the number of sellers is low is that since there is not enough sellers and buyers, there are less deals.

Figure 6 shows comparison between seller's utility and seller's maximum number of items. Figure 7 shows comparison between rate of items sold and seller's maximum number of items. As these graphs show, obviously, our method can gain more utilities and the rate of items sold than the traditional method.

4.3 An example of user interface

Figure 8 and Figure 9 show examples of the user interfaces of *G-Commerce*. The system has been implemented by using MiLog (Mobile intelligent agents using Logic programming) [14]. MiLog has been implemented by using Pure Java. To realize an efficient intelligent agent development environment, Milog provides a hybrid programming environment in which an agent can be designed by logic programming and Java programming. In MiLog, we can create agents that have web-service and access functions. A MiLog agent can behave as a CGI program and can access to other web servers via HTTP.

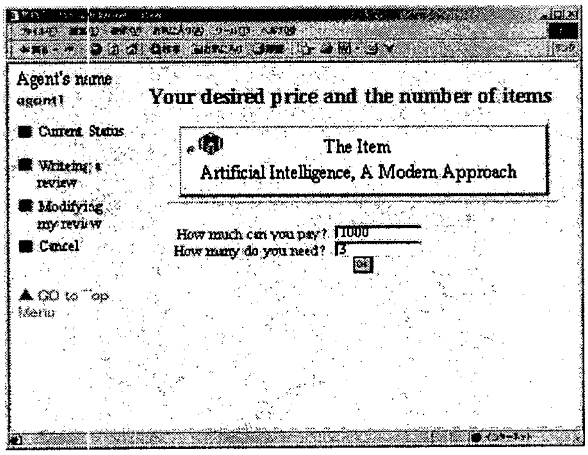

Figure 8. Inputting User's Desired Price and Number of Items

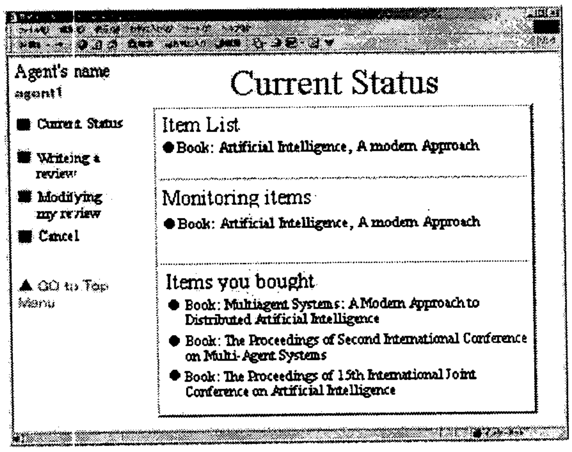

Figure 9. Presenting the Status of Purchasing

The window in Figure 8 shows an user interface for putting user's preferences. An user can access his agent via a web browser. A MiLog's agent has a function to behave as a web server. We utilize this function to allow users to access to their agent. An user can input his desired item and a reservation price in the text box in the middle of the interface.

The window in Figure 9 presents an user interface for showing a current status. Users can know which item is now monitored, which item is now on sale, which item is purchased via this user interface. Also, an user who wants to sell some items can input information on items via a web browser. If an agent could make an agreement, he informs the details of the agreement to his user in order to ask the user whether he should actually make a contract or not.

5 Related Work

In this section, we present related work on our study. We can classify related work into the following two categories: **agent-based electronic markets**, and **shopping information gathering agents**.

Agent-based electronic markets: AuctionBot, eMediator, Kasbah, FishMarket, and Tete-A-Tete can be classified into this category. Our system proposed in this paper is also classified into this category. AuctionBot[20] is an auction server. Users can create auctions to sell their item. In the auctions, agents can bid according to the pre-defined protocol. AuctionBot provides API for users to create agents. Kasbah[3] provides a market place on the Web. Users can create agents that can buy and sell in the market place. In Kasbah, deals between agents are conducted based on a simple protocol. FishMarket[16] provides an electronic auction site. Users can encode several bidding strategies to their agents. Although FishMarket is an experimental system, virtual tournaments have been conducted several times. Tete-A-Tete[8] provide an electronic market. In Tete-A-Tete, agents cooperatively negotiate with each other based on arguments. eMediator[17] is an electronic commerce server and consists mainly of eAuctionHouse and eCommitter. eAuctionHouse is a configurable auction place that supports many auction types. eCommitter is a leveled commitment contract optimizer which can solve the Nash equilibrium thresholds. GroupBuyAuction[21] is an agent-based electronic market on which agents automatically negotiate with each other on behalf of their users. In particular, in the GroupBuyAuction, buyer agents can form coalitions in order to buy goods at volume discount price. The difference between out approach and this approach is the exchanging mechanism among seller agents.

Shopping information gathering agents: Sherlock 2, AuctionWatch, BargainFinder, ShopBot, Jango, *BiddingBot*, Preist's work, and Anthony's work can be classified into this category. Apple's Sherlock 2 is a meta-search engine which can access several search engines on the Internet. Additionally, Sherlock 2 can search a desired item on online auction sites. AuctionWatch[2] is a search engine for items in several auction sites. Users can search their desirable items by providing some kerwords. BargainFinder[4] is a shopping agent for on-line price comparisons. Given a specific item, BargainFinder requests its price from the pre-specific merchant Web sites. ShopBot[5] evolved from BargainFinder. ShopBot can automatically determine how to represent information and queries in the online merchant sites. Jango[6] is an advanced ShopBot, and helps a user decide what to buy and where to buy it. *BiddingBot*[10] is one of the shopping support agents that can actually attend, monitor, and bid in real auction sites. For the *BiddingBot* we have proposed several cooperative bidding mechanisms among agents[11]. Preist[13] and Anthony[1] proposed a SINGLE autonomous agent that can participate in simultaneous multiple auctions.

6 Conclusions

In this paper, we proposed an exchanging mechanism among seller agents for agent-mediated electronic markets, G-Commerce. On *G-Commerce*, seller agents and buyer agents negotiate with each other. In our model, seller agents cooperatively negotiate in order to effectively sell goods in stock. Buyer agents cooperatively form coalitions in order to buy goods based on discount prices. By employing an exchanging mechanism, seller agents can effectively exchange their items in stock. Subsequently, they can sell more items as a group. We implemented an agent-mediated electronic markets based on the negotiation schema we proposed. The results of our current experiment demonstrate our exchanging mechanism can effectively facilitate agent's deals. Furthermore, we present the Pareto optimality of our exchanging mechanism. Since our exchanging mechanism can satisfy the Pareto optimality, our agents can rationally reach an agreement in our electronic market.

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