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A Multi-Attribute Negotiation Support System with Market Signaling for Electronic Markets

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Abstract

Despite the rapid growth of technology and Internet-based markets, many of the current systems limit themselves to price as the single dimension variable and offer, if at all, only minimal negotiation support to the consumer. In the real world, commercial transactions take into account many other parameters both quantitative and qualitative such as product quality, speed, reputation, after sales service, etc. This paper discusses how these multiple attributes can be captured to augment standard negotiation processes in order to support electronic market transactions. Using a combination of utility theory and multi-criteria decision-making, we propose heuristic algorithms to discover potential trades. In addition, the approach is included within a larger framework that incorporates market-signaling mechanisms. This not only allows for the systematic evolution of negotiation positions among buyers and sellers but can ultimately lead towards improving both market transparency and efficiency. To illustrate the multiple criteria model coupled with the dynamic market signaling framework, we report in this paper the implementation of a Web-based clearinghouse that serves the real estate market.

Key words: multi-attribute modeling, market intermediaries, market signaling, negotiation and support

1. Introduction

From prehistoric times man has at every opportunity traded possessions, livestock or otherwise, to enhance the comfort and quality of life. The early trades were barters. The introduction of currency facilitated a fairer exchange of values among the trading participants but scarcity, urgency and above all lack of free flowing information more often than not led to lopsided deals. Today, however, we have come a long way in our appetite for goods and services. Both theoretical advances in economics and progress of technology have opened up new possibilities so much so that the economist's dream of a perfect global market may well become a reality in the not too distant future.

It is increasingly becoming easier to carry out commerce over one of the modern technology marvels, the Internet. Linking products and services to potential buyers in geographically and politically distant locations difficult to reach before can now be done at electronic speeds. E-Commerce, as it is has come to be called, has evolved into a monumental symbol of modern trade. The US retail e-commerce reached \$25.8 billion in 2000 (CIO 2001) and is expected to reach \$300 billion by 2003 (Perry and Schneider 2001). By 2005, the global market for multi-access Internet services is estimated to reach \$1.3 trillion (Ovum 2001).

The primary participants to a business transaction are the buyers and the sellers. But many a time, acting as an intermediary, a broker is also party to such transaction. To be useful, electronic marketplaces must be supportive of these players (For a survey of the lack of negotiation support capability, see for example, Yen et al. 1996). In addition, the marketplace environment must foster various types of trade they choose to take part in. Six types of trade have been discussed in literature (Liang and Huang 2000). These are: barter, bargaining, contract, clearing, bidding and auction. Barter is a trade type in which both parties offer their goods/services for exchange. Bargaining uses negotiation between buyer and seller until an acceptable deal is struck. Contract is a trade type in which both buyer and seller are governed by a set of mutually agreed rules. Clearing, on the other hand, involves multiple buyers, sellers and brokers. A good example is the stock exchange. In bidding, there is one buyer and many sellers. The buyer evaluates the bids received for an announced product or work and chooses the best. The final type of trade that the electronic marketplace must support is auction. It involves a broker who matchmakes potential buyers and sellers for a commission. The seller sets a reservation price for the product and potential buyers bid sequentially until it is sold to the highest bidder. Auctions on the Internet bring buyers and sellers together in a central worldwide marketplace, unencumbered by intermediaries and, to a large extent, outside regulation. It helps expand reach into the market and reduce the cost of goods and services. Transaction times can be shortened from weeks to days. The online auction transactions in 2000 amounted to \$29.84 billion in 2000; current projections indicate that trading via auctions will reach \$52.6 billion by 2002 and further increase to \$746 billion by 2004 (Mitchell 2000).

The purpose of this paper is to provide a comprehensive framework for designing a clearinghouse for supporting market transactions. The proposed framework uses multi-attribute utility as a means to provide traders decision processes that go beyond the current trading mechanism based solely on prices. In addition, our framework also integrates the use of Web-based technology as a vehicle offering information channels to enhance market transparency and efficiency.

2. Toward a framework for electronic markets with negotiation support

From the above discussion, it can be seen that computer systems to support the electronic marketplace must have a wide range of functionalities. Comparing and evaluating them is as important as it is challenging. Knowledge of the overall components and characteristics of the market as well as their interactions are essential in identifying the taxonomy of capabilities a computerized system must possess.

2.1. Ability to trade a wide range of goods

One of the classifying factors for electronic marketplaces is the type of goods traded. Traditional economic theory points out that the type of goods is an important factor in the trading scenario. Therefore, many traditional auction services were established for trading specific type of goods such as perishables (e.g. produce), and rare or second-hand goods that are characterized by the limited market and difficulty in assessing an appropriate price. In fact, early Internet auction sites gained popularity by providing marketplaces for those kinds of goods. However, today's auction items are not limited to a few categories. Currently, a wide range of goods is traded through Internet auction sites, with an increasing variety of digital goods (e.g. software, digital books, digital music).

Theoretically, an auction is suitable for trading standardized items (e.g. stock), which do not require a complex ontology to describe so that the negotiation efforts can be focused on price. More recently, Internet auction sites received publicity as a potential marketplace for trading intangible goods such as expertise and intellectual property (e.g. experts-exchange.com). Such sites use social ratings or reputation mechanisms as the means of evaluating quality for these intangible goods.

2.2. Products specifications

Different users tend to specify the same product in assorted ways. Product description is a problem not only in the matchmaking process, but in the settlement process as well. For example, malicious users can intentionally avoid specifying inferior features if there is no standard set of attributes. This is often the case in classified ads in newspapers. Having a standardized set of specifications will also help buyers/sellers access multiple electronic marketplaces simultaneously. As discussed later in this paper, software agent technology can be used to facilitate the creation, dissemination and updating of information regarding product specifications.

Product specification is also an important issue for using a multidimensional auction. Without the agreed upon set of attributes, cooperative negotiations are not feasible. There are at least two possibilities for solving this problem. One approach is to force the user to follow a pre-defined set of specifications according to the type of products (e.g. Personallogic.com). This way we can standardize product description. However, it is impractical to identify the necessary dimensions of all goods. The other approach is to leave product description to either the sellers or buyers who initiate the trade. In this case, we do not have standardized product descriptions, but we have more flexibility. This is an area that requires further research.

2.3. Bargaining, auction and negotiation support

Previous research used the number of participants as a major dimension of classifying EC (Beam 1999; Bichler 2000). Even before Internet auctions became popular, this kind of taxonomy was widely used in the NSS research area (e.g. bilateral vs. multilateral). Table 1 shows the taxonomy of negotiation type based on the number of participants. The majority of auction services fall into the category of one-to-many (1:N) whereas mediated matching services fall into the many-to-many (N:N) category.

Table 1. Taxonomy of market mechanisms based on the number of participants

Seller/Buyer	ONE	MANY
ONE	Bargaining	Auction
MANY	Reverse auction	Mediated transaction

Since auctions provide an efficient way for price determination, many electronic marketplaces have been built based on the auction mechanism. However, there are varieties of auction mechanisms and each has its own strengths and weaknesses. Most seller-centric electronic marketplaces (i.e. B2C or C2C) provide a variety of auction mechanisms including English, Dutch, and multiple-unit uniform price auctions (Bichler 2000). On the other hand, buyer-centric electronic marketplaces (i.e. B2C or B2B) mainly use the reverse auction mechanism. The reverse auction mechanism is a familiar form to government or corporate purchasing departments.

A final and important role of electronic marketplaces is to ensure that the transaction is completed satisfactorily. To do this, they need to provide a banking service, confirm payment is settled, and resolve disputes among the trading partners. In fact, one of the major complaints from Internet auction services has been buyers' non-payment for goods received. This paper found a number of Internet auction services attempting to solve the problem. For example, Priceline.com has a unique feature to ensure payment. When both parties have agreed to the price and terms, Priceline.com (as opposed to the buyer) pays the bill using credit card information which the buyer registered before the transaction began. In this way, an intermediary ensures the transaction is completed, as soon as agreement is reached. Non-payment is not possible, as a credit reversal would be a separate transaction. On the other hand, few electronic marketplaces provide direct shipping service. Most electronic marketplaces let trade partners use a third party carrier. This strategy, i.e. letting them handle the shipping process by themselves, sometimes works for smaller transactions, but in many B2B transactions, shipping is such an important issue that the electronic marketplaces need to include this feature.

From the foregoing discussion of the existing literature, several functionalities required of an automated system that would serve electronic markets and provide negotiation support effectively are identifiable. However, few electronic marketplaces provide negotiation support for other than price. Some Internet services (e.g. Rbuy.com) provide negotiation support to help both trading partners reach a consensus. However, the algorithms used in these automatic negotiations are too simple to be widely used in real transactions. On the other hand, a few of the other Internet auction services (e.g. eBay.com) provide a "proxy bidding" service which automatically increases bidding until the bidding price reaches users' willing-to-pay price. Although this proxy bidding may relieve users from the burden of constantly monitoring the bidding process, it is too simplistic to be considered a negotiation support. The more promising method of providing negotiation support currently being investigated is by using a multidimensional auction mechanism. Few electronic marketplaces employ multidimensional negotiation support mechanisms since research in this area is still in its infancy. These electronic marketplaces would aim to find optimal goods and partners based on the user's preference not only on price, but also on other variables such as quantity and shipping option. Kersten (2001) provides a comprehensive review of the theoretical foundation leading to scientific approach to implementing effective negotiation.

3. Multi-attribute modeling in electronic markets

We have seen that electronic markets in general serve as the intermediaries between buyers and sellers. Acting as a broker or a dealer, an electronic market allows consumers to purchase products or services electronically without contacting a large number of vendors individually. Any computerized system designed to automate the mediating functions need to meet three essential requirements: (i) capture the buyer and seller preferences across multidimensional attributes, (ii) identify algorithms/processes leading to their Pareto optimality, and (iii) incorporate signals and behavior of a dynamic market during the time the negotiations occur. This approach allows integrating traditional analytic techniques in negotiation such as multi-criteria decision-making with the overall enhancement in the market efficiency and transparency (for a recent review of research and practice in multiple criteria decision making, see for example Haimes and Steuer 2000). In the following discussion, we shall look at one of the first steps performed in an auction, viz. order matching. We shall then expand it to include the multi-attribute and utility evaluation.

3.1. Order matching for transaction

A transaction occurs whenever a bid crosses an offer on the basis of certain trading rules. A database tracks the standing buying and selling orders that already been received but failed trade. When a bid arrives, the clearinghouse attempts to match the buy order with one of the standing sell orders, and vice versa. If there is no standing counter orders, bids and offers will be registered as standing orders until eligible counter orders received or traders cancel their orders.

In principle, the transaction for a bid or for an offer is 1-to-N matching, i.e. matching of one bid (or offer) against multiple standing sell (or buy) orders. Different trading mechanisms can be employed depending on the types of markets and products sold. In this research, we approach the transaction matching by multiple criteria analysis. We only consider fixed and durable assets, such as, houses and cars, to be supported by the electronic market we designed. The reason is that when people buy cars, they consider price, look or model, comfort, performance, and gas consumption. It is different from the electronic trading systems that support stocks and bonds where only price, quantity, and time are taken into consideration. Our aim is to focus on products, where negotiation involves more attributes and the negotiation strategies are more complicated.

3.2. Utility formulation of traders

Utility theory has been extensively discussed in the literature and it has proved to be a robust approach to capture the decision maker's preferences (for a recent review of utility, see for example Luce 2000). The heuristics presented find their roots in these proven theories. In particular, it adopts the weighted linear utility model – a theoretically sound concept yet relatively simple and transparent enough to implement.

Let us assume that n(t) sellers and m(t) buyers enter the market at time t; thus, i = 1,…, m(t); and j = 1,…, n(t). The information of the i-th bid is represented by an array that contains l requirements $b_i = \{b_{i1}, b_{i2}, \ldots, b_{il}\}$, which include the price and other possible requirements of the product, and an array of l integers $bc_i = \{bc_{i1}, bc_{i2}, \ldots, bc_{il}\}$ indicates the conditions of the requirements: 0 for "does not care", 1 for "negotiable", and 2 for "not negotiable". The information of the j-th offer are represented by arrays o_j and oc_j which contain similar information as b_j and bc_j. The ranges of the requirements or conditions, such as price, can be either ordinal or cardinal. Within the range of each requirement, the utility is strictly decreasing. There are two possibilities that a requirement b_{ik} of buyer i and a condition o_{jk} of seller j are satisfied:

- Either buyer i or seller j indicates he or she does not care about the requirement. That is, $bc_{jk} = 0$ or $oc_{ik} = 0$.
- Either seller or buyer, the requirement asked or condition specified is accepted by the counterpart.

The lexicographic strategy requires listing the attributes of products in their order of importance. In repetitive judgmental discrete decision-making with multiple criteria, the decision maker usually behaves as if there is a set of appropriate criteria weights such that the decisions chosen are based on the weighted sum of all the criteria.

The bigger the utility function value is the better that it can be matched by the buyer's and seller's bids. The linear utility function is calculated as follows:

1. For the buyer's bid b_j and bc_j, ignore the attributes for which bc_j value equals 0.
2. Choose weights for the objectives or use an implied set. As an initial step, the implied set of weights can be derived from experts opinions, $W_i = \{W_{i1}, W_{i2}, \ldots, W_{il}\}$, which tend to reflect trade off among different criteria. The sum of weights equals 1.
3. Assuming linearity, this set of weights is used to generate the solution. Access the list of goods to be selected with their described characteristics, and then, calculate the utility based on the following function:

$U(x) = S_i^{\,1}(W_i * (o_{ij}/b_{ik}))$

If the value of bc_j is equal to 2, o_{ij}/b_{ik} will be zero if o_{ij} is not better than b_{il}.

If the value bc_j is equal to 1, when $\tau_{b,i} \leq o_{ij} \leq \mu_{b,i}$, value of o_{ij}/b_{ik} will be $|(o_{ij} - \tau_{b,i})| / |(\tau_{b,i} - \mu_{b,i})|$, or it will be zero, where:

W_i = weight of each objective
o_{ij} = characteristics of goods being sold
b_{ik} = buyer's criteria
$\tau_{b,i}$ = reserved level of the buyer, and
$\mu_{b,i}$ = aspiration level of the buyer.

Identify the linear function that yields the highest value and insert it to the top of the matching list and show the rest of the orders that at least have 90% (or any arbitrary threshold) of their attributes that match the requirements set by both sides.

Table 2 shows an example of criteria defined by a prospective homebuyer in a real estate market.

Table 2. Example of a home buying order

Point of view I	B_I	Weights	Negotiable
Price (HK$1,000)	$3,500–$3,725	0.4	yes
Size (SF)	800–700	0.1	yes
Bedroom number	2	0.2	no
Number of living rooms	1	0.05	no
Building age (year)	<10	0.05	no
Floor	>8	0.1	no
View	ocean view	0	do not care
Location	South Island	0.1	no

When a bid like the one in Table 2 is submitted, the clearinghouse immediately matches the buying order with all the standing selling orders. First, it checks the condition of each requirement and chooses the set of implied weights, which were obtained from a survey with local real-estate agents. For example, if the buyer does not care about "Ocean View", system will select the implied set where the weight of "Ocean View" is set to zero.

Second, it searches the database of standing selling orders to find the records which are satisfied with the condition of fixed requirement, and also they fall between the desire values and reserved values that set by the buyer. For example, the example as shown in Table 2 searches for selling order or orders that satisfy the requirement of bedroom room number (not less than 2), living room number (not less than 1), building age (less than 10), floor (higher than 8), location (South HK Island), price (between HK$3,725,000 and HK$3,500,000), and size (between 700 and 800 sq. ft.).

Third, it calculates the linear utility function with multiple weights to determine the satisfactory degree of each criterion. It also shows the listing that based on the results of utility function calculation. Therefore, after having all the results, the clearinghouse awards the buyer the bid that with the most matched sell order. Normally, the last attribute considered is time (order arrival time). If two counter orders have the same values over all attributes, the First-In-First-Out (FIFO) principle will be applied to break the tie. All incoming orders that are not matched in the transaction phase will be forwarded to the negotiation phase.

3.3. Models of negotiation

Negotiation process is a process by which a joint decision is made by two or more parties. The parties express contradictory demands and then move toward agreement by a process of concession making or identification of new alternatives to keep the negotiation moving.

In any negotiation process, concession is usually needed to generate agreement, to prevent the other party from leaving the negotiation, or to encourage the other party to make reciprocal concessions. A concession is a change of offer in the direction that increases the utility of the other party or sacrifice one's own interests or benefit. This is based on the concept of zero-sum game, that when one side makes sacrifices, the other side is believed to receive what the other side has sacrificed (for a more detailed discussion, see for example Kersten (2001)).

The level of aspiration is the level of benefit sought at any particular time. That is, the value to the bargainer of the goal toward which he or she is striving. Generally, limit tends to remain constant over time, whereas aspiration eventually declines toward limit. Limit and level of aspiration are strongly related.

It is very common for selling (buying) bargainer to start with a high (low) bid, well beyond the limit and aspiration levels. This move creates the room to concede in the latter stages of negotiation. The motivation of negotiators, who stick to high demands and slow concession rates, is that they try to give the impression of full of firmness and have desirable or favorable alternatives. They have to use the bargaining strategies or tactics in order to fulfil their plans. However, this is not the case when perishable goods are traded. This is because one of the characteristics of perishable goods products is that their prices drop sharply and it might create significant losses if a transaction cannot be made during the current transaction period. Bargainers often experience time pressure, which is due to the foreseeable costs or increase of risks if negotiation needs to be extended. Time pressure helps in lowering the demands and making people more willing to concede, which has a greater effect on the concession rate and how fast that a deal can be made.

Intelligent electronic market with negotiation support proposed in this paper is to help users evaluate each offer and counter offer by using utility functions and dynamic market information. Competitive environment is created through market signaling game and simultaneous negotiations with several counterparts. By using this system, users are expected to be able to more quickly reach satisfactory solutions or achieve better payoffs. Market signaling is discussed in more detail in Section 4 of the paper.

The negotiation is initiated when buyer and seller try to decide about the transaction terms in more detail. A bid or an offer may fail to be transacted, although some standing counter orders may exist. Such transaction failure is the result of discrepancy between buy and sell orders in terms of price or other attributes. The negotiation process is designed to provide traders with advice on how their buying and selling intentions can be realized by adjusting their utilities to reflect the market conditions. It is up to the traders whether to make concessions or not. Such advice would be most valuable to traders who want to execute transactions promptly and, therefore are willing to negotiate on the terms of transactions. Since the electronic market produces the advice based on the pool of information about all the standing counter orders, traders can expect that the advised compromise could be the most appropriate under the current market condition.

For negotiations, bc_i and oc_j will be considered in addition to b_i and o_j; that is, not only is the set of multiple attributes need to be identified, but each attribute in the set must be assigned values of 0, 1 or 2. First, we may need only the values of 1 (negotiable) and 2 (non-negotiable) for bc_i and oc_j, since a 0 (does not care) on either side automatically makes the attribute satisfied. In principle we need to consider only one incoming order against one or more than one standing counter orders for negotiation. Therefore, it is possible to produce some heuristics to support negotiation. Following are the notations to describe the heuristics.

Notations
AS : attribute satisfied.
ANS : attribute not satisfied.
NS_i : set of negotiable selling orders for buying order i.
NB_j : set of negotiable buying orders for selling ordering j.
FAB_i : set of non-negotiable (fixed) attributes of buying order i, where $bc_{ik} = 2$; for k = 1 ,.., l.
NAB_i : set of negotiable attributes of buying order i, where $bc_{ik} = 1$; for k = 1; …l.
FAS_j : set of non-negotiable (fixed) attributes of selling order j, where $oc_{jk} = 2$; for k = 1; …l.
NAS_j : set of negotiable attributes of selling order j, where $oc_{ik} = 2$, for k = 1; …l.

In reality, the set of attributes for buying order and selling order may be different. But for simplicity we assume they are the same.

Heuristics principles
We define the following principles for our algorithms:

1. The smaller the number of negotiable attributes, the better the deal.
2. Attributes are ordered by decreasing importance.
3. Negotiation is first attempted over negotiable attributes. Non-negotiable attributes are considered only when the first attempt fails.
4. Tie-break rule: if the number of attributes to be negotiated are the same, the counter order with minimum discrepancy will be selected to be negotiated.

For purposes of clarity, we present two sets of procedures that provide negotiation support for the electronic market. We start with a simple scenario in which all but one attribute needs to be negotiated among traders. Within the single attribute approach, we propose two different cases, one when the attribute is negotiable and the other when it is not negotiable. In Section 3.4, we relax the single attribute constraint altogether and discuss the general algorithm for finding an agreement when multiple attributes are simultaneously considered.

Case 1 – Heuristics for single attribute negotiation (for buying order i): When k-th attribute is in the negotiable attributes of buying order i, that is, $k \in NAB_i$

Step 1: Find the set of negotiable selling orders NS_i for buyer order i where all the attributes are satisfied (b_{im} AS o_{jm} for all m) except k-th attribute (b_{ik} ANS o_{jk}).

1. If no counter order exists (NS i = {}), go to step 4.
2. Otherwise, go to Step 2.

Step 2: Find the subset of negotiable selling orders for i-th buying order ($NS_i^k \in NS_i$) where k-th attribute is negotiable ($k \in NAS_j$). Then find the one that with smallest discrepancy over k-th attribute (if there is a tie, select both j).

1. If no such counter order exists (NS_i^k = {}), go to Step 3.
2. Otherwise, initiate a middle-point negotiation where m_k is selected to be the mid-point between b_{ik} and o_{jk}, that is, $m_k = (b_{ik} + o_{jk})/2$. Then the advice will be sent to both sides and we will wait for their reactions. Note that the concept of middle point would work only with continuous values (such as monetary terms). For discrete values – such as "Ocean view", "Garden View", the system would point out the "value" difference to the users with a ranking based on their announced preferences, and let them decide.

Step 3: Find the subset of negotiable selling orders for i-th buying order ($NS_i^k \in NS_i$) where k-th attribute is non-negotiable ($k \in FAS_{j)}$. Then find the one with smallest discrepancy over k-th attribute (if there is tie, FIFO is applied).

1. If no such counter order exists (NS_i^k = {}), store the buying order i as a standing order and wait for the next cycle.
2. Otherwise, initiate the negotiation for buyer i. In this case, we cannot use mid-point negotiation, since k-th attribute is not negotiable to j-th seller. Instead, we have to ask the buyer whether s/he would like to accept the offer from seller j that with the smallest discrepancy.

Case 2 – Heuristics for single attribute negotiation (for buying order i): When k-th attribute is in the set of non-negotiable attributes of buying order i, that is, $k \in FAB_i$

Step 4: The subset of negotiable selling orders for i-th buying order NS_i where all the attributes are satisfied (b_{im} AS o_{jm} for all m) except k-th attribute (b_{ik} ANS o_{jk}) and $k \in NAS_j$.

1. If no such counter order exists (NS_i = {}), store the buying order i as a standing order and stop.
2. Otherwise, go to Step 5.

Step 5: Find the subset of negotiable selling orders for i-th buying order ($NS_i^k \in NS_i$). Then find the one that with smallest discrepancy over k-th attribute (if there is a tie, select both j). Then, initiate the negotiation for buyer i. Send the offer of buyer i to the seller j and ask whether it can be accepted or not. If yes, the negotiation is done, otherwise, move on to the next standing seller in NS_i^k. The negotiation process continues until the beginning of the next time period.

3.4. Multiple-attribute negotiation

In most cases, traders are willing to settle the less important attributes first so that they can focus on the most important ones, for example, price. However, it is often that there is more than one attribute that does not match. The negotiation process for multiple attributes is more complicated. For this research, two approaches are provided. The first uses the same heuristics as the single-attribute negotiation. The second is a two-stage process, which settles the less important attributes first and then the most important attribute, in most cases – price. As mentioned earlier, it combines the utility theory, multi-criteria decision-making, and the concept of convergence. Non-negotiable attributes are constraints and must be satisfied before the negotiation heuristics takes place.

3.4.1. First approach

Two guidelines recommended for the first approach are:

1. The set of negotiable attributes k should be treated as a package.
2. The system should automatically create the negotiation partners NS_i^k.

As mentioned earlier, the attributes have an order of importance. It may be possible to determine the order of counter orders in NS_i for negotiation based on the order of attributes. In order words, identify which seller should negotiate first from NS_i.

Case 1 – When the set of attributes k is a subset in the negotiable attributes of buying order i, that is, $k \in NAB_i$

Assume k_1, k_2 and $k_3 \in NAB_i$. If there are three counter selling orders in NS_i, it is possible to decide which one to negotiate first with buyer i. For instance, seller 2 is chosen as the first candidate for negotiation. If his or her k_1 and $k_2 \in NAB_i$, $k_3 \in FAB_i$, and $k_1 \in FAS_j$, k_2 and $k_3 \in NAS_j$, then the following guidelines can be produced.

1. to buyer i, initiate negotiation over k_1,
2. to seller 2, initiate negotiation over k_3,
3. to both buyer i and seller 2, initiate a middle-point negotiation over k_2.

Thus, the system advises buyer i to relax requirements over k_1 and k_2 (k_1 is value of seller 2 and k_2 is a middle point between buyer i and seller 2), and advises seller 2 to relax requirements over k_2 and k_3 (k_3 is the value of buyer i and k_2 is the middle point between seller 2 and buyer i).

Case 2 – When the set of attributes k is a subset in the non-negotiable attributes of buying order i, that is, $k \in FAB_i$

As in the case of the single attribute negotiation, further analysis can be done to find out counter orders that are willing to negotiate on the attributes that are non-negotiable for buyer i.

3.4.2. Second approach

The second approach uses the combination of utility theory and multi-criteria decision making to develop the negotiation rules. The first objective is the most important attribute, for example, price, and the second objective is the total utility of the other attributes. For example, after buyer i places an order for a product or a service, the clearinghouse sets the price bi1 (t) aside and selects the feasible set NS_i based on total utility $U_i(w)$, where

$$U_i(w) = \Sigma_{k=2}{}^m (W_k * (o_{kl} / b_{kl})).$$

The utility calculation is similar to order matching one. All the selling orders in NS_i are ranked according to $U_i(x)$. Note here, we add (t) to both buying price and selling price, because the negotiation is a dynamic process. The price o_{j1} (t) of the first selling order in NS_i now is compared with b_{i1} (t). If $b_{i1} (t) - o_{j1} (t)$, the transaction pair is identified and b_{i1} (t) is the transaction price. Otherwise, the clearinghouse on behalf of the seller j makes a recommendation o_{j1} (t) to buyer i.

For the buyer i, the objective is to minimize the buying price b_{i1} (t), such that

$$\tau_{b,i} \leq b_{i1} (t) \leq m_{b,i}.$$

For the seller j, the objective is to maximize the selling price o_{j1} (t), such that

$$\mu_{s,j} \leq o_{j1} (t) \leq \tau_{s,j}, \text{ where}$$

$\tau_{b,i}$ = aspiration level of the buyer,
$\tau_{s,j}$ = aspiration level of the seller,
$\mu_{b,i}$ = reservation level of the buyer, and,
$\mu_{s,j}$ = reservation level of the seller.

Offers from the buyers and sellers are between their respective reservation and aspiration levels. For the buyer

$$b_{i1} (t) = b_{i1} (t-2) - \theta_i (o_{j1} (t-1) - o_{j1} (t-3)),$$

and, for the seller

$$o_{i1} (t+1) = o_{i1} (t-1) - \alpha_j (b_{j1}(t) - b_{j1} (t-2)),$$

where $(o_{j1} (t-1) - o_{j1} (t-3))$ and $(b_{j1} (t) - b_{j1} (t-2))$ are the most recent concessions made by the buyer and seller. θ_i and α_j are the coefficients of the parties' tendencies to reciprocate and they can be time dependent. If θ_i and α_j are both negative, the negotiation is moving toward a compromise.

In order to make the negotiation process move forward, certain concessions are required. However, in order to make concession and also make more reasonable offers or counter offers, buyers or sellers need to have sufficient information about the market. In such case, market will move toward the equilibrium point faster.

It is important to note that the proposed algorithm is based on value functions. As such, it does not explicitly take into consideration any attitude toward risk of the decision makers as it is commonly formulated in investment portfolio analysis. As a multi-attribute model, it is, however, possible to include risk as an additional attribute to the decision model.

4. Market signaling in bargaining and negotiation

The intuitive reasons for gathering information is straightforward – to reduce uncertainty about future and to make choices that have better chances for better payoff. Decision makers who face uncertain prospects search for information with the intention of reducing uncertainty. In reality, we rarely have access to perfect information. Further, our information sources are limited and sometimes some information about market activity might not be so convenient to obtain.

Market signaling allows a situation of incomplete information to become closer to that of complete information. Signaling will also help establish equilibrium in any industry where it is commonly and extensively used (Cho and David 1987). For example, employers hire workers based upon such signals as education, job experience, and references, because the individual applicants' productive capabilities are difficult to determine before hiring. Demographics and credit information act as signals for banks to determine whether or not to grant loans or credit cards to applicants. Market signaling has been used in the development of our intelligent clearinghouse as an incentive structure of negotiation process. This allows real-world negotiations to take place in a market environment where the players are constrained by imperfect, incomplete and often asymmetric information. The competitive advantages of market signaling are many. Signaling provides efficiency and ease of communication among negotiators. It makes negotiation process more efficient and transparent, which has significantly reduced the possibility of deadlock.

4.1. Channels to support signaling

Economists have attempted to model the role and impacts of market signaling in decision making. Baysesian probability is a common approach to determine optimal decision making under incomplete – but improving – information. In our system, we view an intelligent market as one that allows negotiators send signals to opponents to create favorable impressions, or more precisely, to affect the opponents' subjective probabilistic beliefs about their positions and market condition. For example, recent transactions of similar apartments should have impacts on the process and result of negotiation. To send a signal, a sender can selectively "leak" information to his or her competitors. The competitors can then adjust their reactions by better understanding of the sender's intention and the reasoning behind such action (Engers 1987). If the sender is credible, the competitors' reactions will be timely and consistent with the signals they received. With the supports from network infrastructure and well-structured information delivery process, competitors are also able to assess and evaluate these signals easily, accurately, and respond quicker. In this intelligent electronic market, clearinghouse guarantees the credibility and reputation of information sources by careful selection of such sources.

Figure 1 illustrates three signaling channels that can affect the status of pending negotiations. The first is the property market activity channel that supplies information on all transactions in the marketplace. The second is the price trend channel, which is a channel to support transmission and dissemination of historic data. The opponent negotiable set

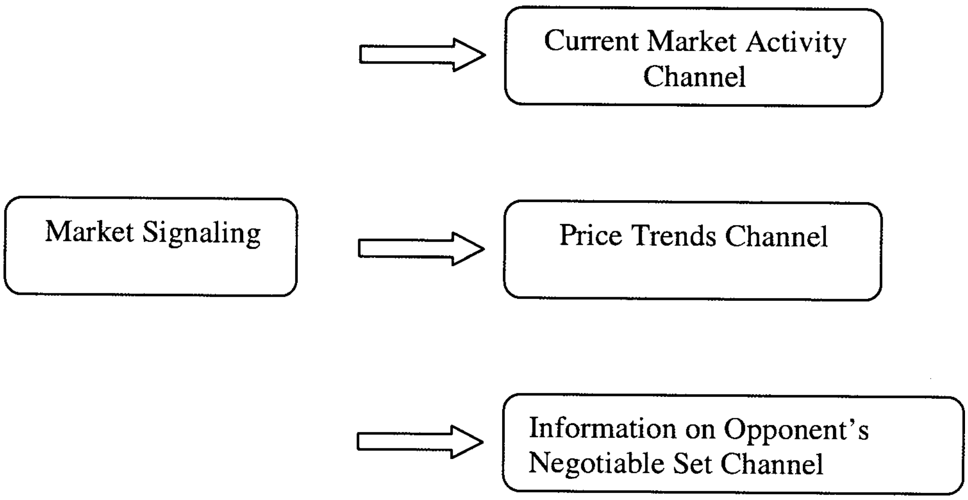

Figure 1. Channels that support market signaling.

makes up the final channel used in our model. When a buying search with selection criteria arrives, the searching agent retrieves all the qualified candidates to form the candidate set. The buyer can choose the candidates to form the negotiation set. Simultaneous negotiations with several candidates are encouraged to create higher competition among candidates. Results of each round of negotiation are intentionally "leaked" to the opponents to create pressure to keep the negotiation process moving toward the direction of the user. In sum, all these three channels deliver market signals to support the negotiators to evaluate the offers. Further, the significant unintended but useful outcome is the resultant market efficiencies and quality decisions.

In this paper, due to the desire to keep the system as transparent to the users, we look at market signaling as a feature that would provide the users with context-sensitive information using software agents to search for information. However, we do not intrinsically embed information into our heuristics.

4.2. Market signaling and the role of the Internet

With the development of the Internet, market signaling is more efficient, cheaper, and faster. Technologies provide the solutions for dealing with information at different levels of abstraction and in varying media forms, fusing overlapping information from multiple sources into integrated ones, monitoring and reacting to changes or patterns of changes, and occurring across the networked information sources. In other words, providing access to heterogeneous sources based on a general customer base is an important design criterion. The active and integrated exploitation of information from these sources is one of the real concerns to applications of online information sources. What we propose here is to use software agent technology (Blanning and Bui 1999; Bui 1999) to accomplish information gathering and analysis to make market closer to the one with complete information. Thus, with the help of a network of information sources that contain data resources to track and trace market events and activities in special application domains, such as, real estate and financial investment; as well as utilizing information agents that perform query/statistical data analysis activities over dynamically changing, distributed, and heterogeneous resources to collect texts and image data, one can transmit market signals more efficiently to help negotiators to evaluate each counter offer.

5. Implementation

In order to validate the proposed multi-attribute model with its facility to respond to market signals, we have developed a number of prototypes. The first prototype system was created to test the first algorithm (see section 3.3.). The prototype uses the real estate market in Hong Kong and its detailed features and the lessons learned from the system was reported by Hu (1999). This first version was offline as the research was completed. A second version to test the second algorithm is being tested at California State University, Northridge. In this section, we briefly go over the major characteristics of the two prototypes.

5.1. Use case analysis

The domain of the application was the real estate market in Hong Kong. The direct players in the system were the sellers, the prospective buyers, and the brokers. Indirectly, the market also participated by sending appropriate signals to the direct players. The primary actors and system processes are shown in Figure 2. A real estate transaction typically begins with the listing of a property by a seller with a broker. In addition to price, the seller intimates his/her attribute set of interest and the corresponding levels of willingness to negotiate them. A prospective buyer contacts the broker with his/her own attribute set. The current listings are then searched and potential properties are matched and their owners are contacted. The broker begins a negotiation process at this point. Market trends are continuously taken into account as each negotiation cycle proceeds until an acceptable overlap in the values of the attribute sets of the buyer and seller are reached. The actual sequence of events is illustrated in Figure 3. The system prototype was implemented on the Internet for experimental studies. The home page is shown on Figure 4.

5.2. Agents architecture

Intelligent software agents were chosen as the mechanism for performing the activities shown in the sequence chart. This is because we wanted the system to evaluate offers, counter-offers and market signals using the model presented earlier and generate efficient solutions transparently with minimal interactions from the participants. The traditional

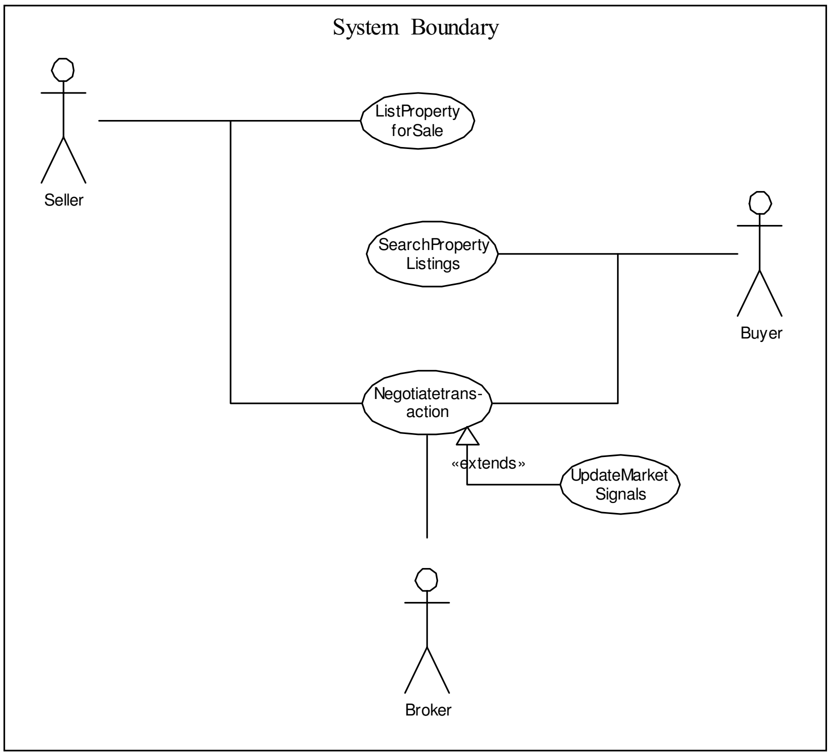

Figure 2. Use case diagram of the prototype.

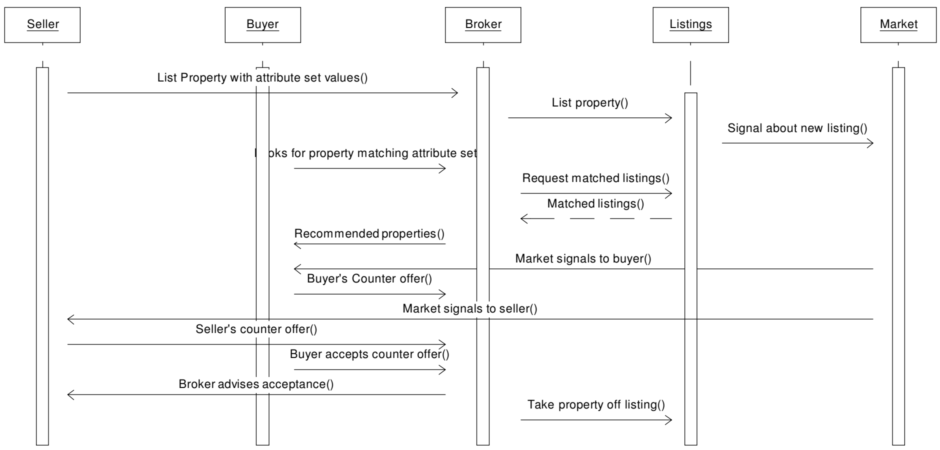

Figure 3. Sequence diagram showing order of message passing among objects.

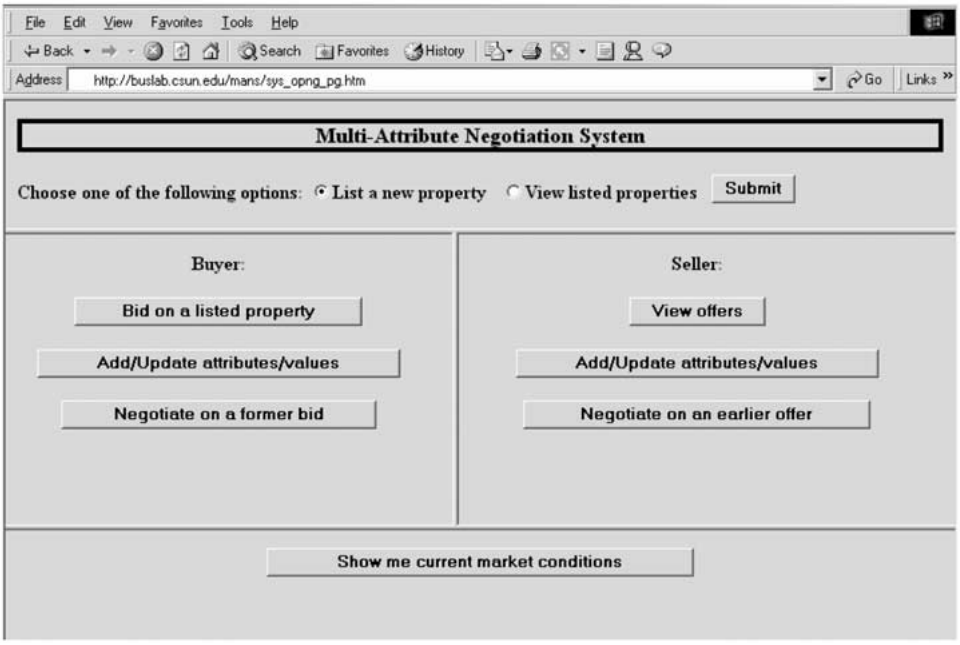

Figure 4. The homepage of the multi-attribute NSS for a real estate market.

approach to the development of software applications was a reactive one, in which the computer was programmed to react to the user's instruction. Instead, the software agent approach is a pro-active one, in that the user specifies what he/she wants the system to accomplish, and the latter performs the tasks on behalf of the user. By analogy, a software agent mimics the role of an intelligent, dedicated, and competent personal assistant (e.g. a secretary of a busy executive, or a consultant or a sale agent in real estate for homebuyer or home seller). Six agents are used in the prototype. They are: matching agent, price analysis agent, news agent, signaling agent, rating agent and price recommendation agent. The overall agent architecture used in the implementation is shown in Figure 5.

5.2.1. Matching agent

Matching agent is the first agent of the system. There are three tasks performed by matching agent.

- Based on user's request, it gathers and filters information and data. Data and information to be collected by this agent must satisfy the criteria that specified by the user, for example, from which source, such as, web site, or relate to which property, such as, Laguna City or South Horizon.
- It also accesses database for the data about the homes that meet the criteria set by the potential buyer.
- It also presents the results of matching based on the calculation of user's multi-utility function.

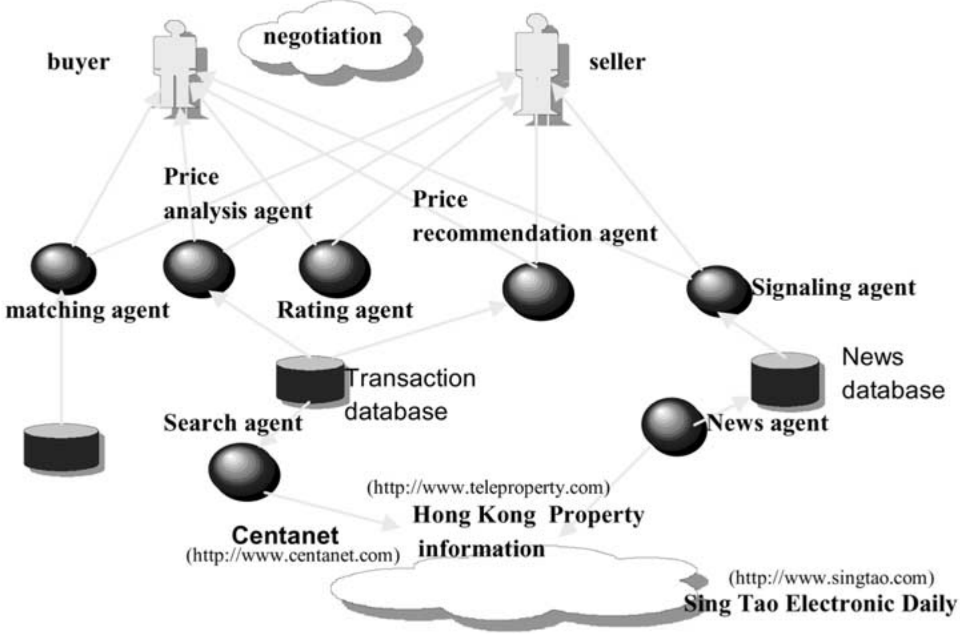

Figure 5. Software agents and their functional tasks.

Home matching process can be treated as a multiple criteria decision problem. Since when buyers consider buying homes, they consider not only price, but also size, location, numbers of bedrooms and living rooms, community, school district, etc. Based on the local situation in Hong Kong, region, building name, view, floor, size, bedroom number, living room number, and price are the most common set of attributes to form the decision space (Bui 1987; Fama 1970). Matching agent was programmed by Active Server Page (ASP) language. We also use the interactive form to receive the criteria from user and the server side database object "ADODB" to create the connection to retrieve the needed data. Utility calculation was done by the module that written in VBScript that runs on the server side. The best matching results are presented to the user by creating a dynamic HTML. Use the algorithm described earlier, the results of a home search are shown in Figure 6.

5.2.2. Rating agent

- It is an agent that evaluates each candidate in each round of negotiation. The evaluation on each counter offer was based on the preferences from the user.
- It is also a task agent that calculates the recommended price based on the negotiator's desire price and reserve price.

We use the following equation to calculate the degree of user's satisfaction to each of the counter offers. If the counter offer falls between the reserve price and the desire price:

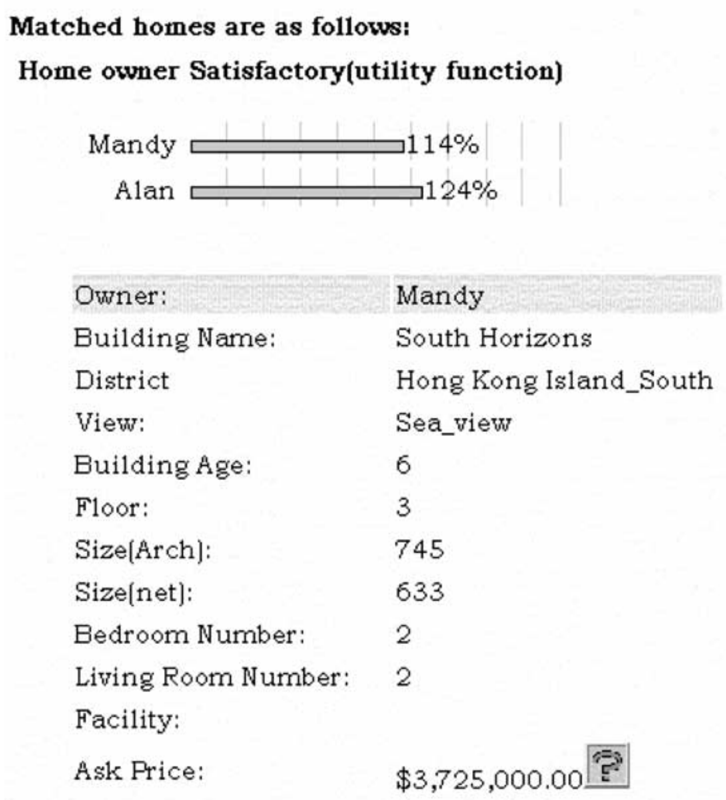

Figure 6. Results of a home search.

For the seller:

$$\text{Rate} = (P_c - P_r)/(P_d - P_r) * 100,$$

and, for the buyer:

$$\text{Rate} = (P_r - P_c)/(P_r - P_d) * 100, \text{ where:}$$

P_r = Reservation price,
P_c = Counter offer price, and
P_d = Desired price.

If the counter offer is better than the desire price, the rate will be greater than 100 and we have to make adjustment. For the seller:

$$\text{Rate} = (P_c - P_d)/P_d * 100,$$

and for the buyer:

$$\text{Rate} = (P_d - P_c)/P_d * 100.$$

If the counter offer is worse than the reserve price, the rate will be less than 0. Then, for the seller:

$$\text{Rate} = (P_c - P_r)/P_r * 100,$$

and for the buyer:

$$\text{Rate} = (P_r - P_c)/P_r * 100.$$

For each round of negotiation, evaluation agent will tell the negotiation participants the degree of satisfaction to each of the counter offers based on his or her desire price and reserve price before the start of negotiation.

5.2.3. News agent

- It is an agent that collects, organizes, and provides textual information, such as news articles, to the participants to improve the market transparency from information sources, such as, websites of news agencies or property agencies.
- It also filters information based on the key words or other criteria that set by the users.

Currently, information collection agent was written in Java and it automatically accesses three selected websites that contain news articles about local property market. It also analyzes contents of the collected articles, organizes the articles according to the topic and estate, and finally makes these articles available to the users.

The news agent is able to retrieve news articles of the special topic from the database based on the user's selection and present them to the user.

5.2.4. Price analysis agent

- It is an agent that provides graphical tool for users to see the trends of price and transaction volume. It shows the curves of price and transaction volume of the specific building of the past two years.
- This agent retrieves and determines the middle, high, and low transaction prices and also transaction volume of the specific building each month. It provides the basis for calculating the recommendation price for each round of negotiation.

The agent code consists of two parts. One is information collection code running on the back end of Web Server implemented by Java application. The other is a Java Applet drawing dynamic price curve and transaction volume curve. The Applet draws the curve based on the data transmitted from the Web Server through "Sockets". This agent provides support for two negotiation phases, before negotiation and during negotiation.

5.2.5. Signaling agent

Signaling agent is a key component of our system, in which the speed of concession or how fast that the market reaches equilibrium or negotiation has an outcome depends on the usage of services that provided by the signaling agent.

- This agent sends the favorable news to negotiation counterparts based on the user's evaluation. It helps user to create pressure to negotiation counterparts in order to move the negotiation in the direction that favors the user.

- News agents automatically collect online news articles from official and reputable web sites of newspapers and government agencies daily and load them to the news database. The average number of news articles been added to the database is around 50 to 60. Since the launch of the Virtual Property Agency in July 1999, we have collected more than 5000 news articles in both Chinese and English.
- This agent provides analysis to the contents to support the user search and retrieve by topic and by property. However, contents of the news articles are not modified to preserve the credibility of signal transmitted through the channel.
- It also collects email addresses from the database of the negotiation counterparts after the negotiation process started. Therefore, only the negotiation counterparts are targeted by the signaling agent.
- It also provides the interface for the negotiation participants to read the news articles to get better idea about the market condition and trend. It also supports the user to select and send the favorable news articles as attached files of email to the counterparts.

The JMail component running on the Server side supports sending emails automatically to the negotiation counterparts. With ASP code, it senses and captures the user's interested building names, retrieves the news titles from property news database, and shows the relevant news to the user. Users are encouraged to choose their favorable signals to create pressure to their counterparts. ASP code collects the negotiation candidates' email addresses and works together with JMail to send the signals as attached files of emails.

5.2.6. Price recommendation agent

- It is an agent that functions when other attributes are satisfied except price. The advice price will be sent to both sides and waiting for their responses.
- This agent provides the recommendation price based on the offer and counter offer from both sides as well as the market condition, such as, price trend.

A simple linear interpolation function is used to calculate the recommendation price. Weight is used to integrate two facts that influence the recommendation price. In this system, we assume that recommendation price is consisted of two parts: part one is the middle-point between offer and counteroffer, which is multiplied by a weight of 0.8 to show its dominance; part two is the middle transaction price of last month, which is multiplied by 0.2. Weight can be adjusted based on the results of testing or aggressiveness of negotiator. The better recommendation price is more likely to create market equilibrium.

5. Conclusion

In this paper, we proposed a number of heuristics that could be used to develop a trading mechanism based on multi-attribute utility theory. To enhance computational efficiency and speed up reaching an agreement, we have presented a number of algorithms that initially focus on the issues that divide the buyers and sellers. At the implementation level, we also discussed the use of Web-based software agents to assume the role of real-time information providers to augment market transparency, and more importantly, to keep market traders with the most updated information. The proposed algorithms and its Web-based implementation framework were implemented for an experimental clearinghouse to serve a real-estate market. Our approach is similar to that on Geng et al. (2001) in that auction design is based on the use of model and technique to reveal information as the process evolves. Our work differs for Geng et al.'s in that we use multiple criteria utility function to reach agreement.

Preliminary results with the system indicated that brokers in general were able to spotlight on the potential parties to prospective transactions in less time. There was also a reduction in the volume of information exchanged through listings, news articles and email for the successful transactions. The system also tended to increase the satisfaction for buyers and sellers with the overall transaction experience, since the incremental concessions both made at each cycle of the negotiation process were clarified and a sense of integrity and fairness was generated among the participants. The buyers and sellers also felt empowered through being able to generate, exchange and thus influence market signals. Further, the final transaction prices were closer to the average market prices implying that such system could be helpful in improving market transparency and efficiency. Study is under way to collect formal data to corroborate the initial findings. Another possible implication of our work is that real estate agents may eventually be superseded by intelligent software systems. This issue of disintermediation will also be addressed in our future research.

Last but not least, trust plays an important role in any sustained business transactions. Empirical marketing data have shown that trust plays even a more critical role in electronic marketplaces. The trust issue arises from the lack of opportunity for physical product inspection. The most common way of increasing trust is to require identification such as an email account from buyers and/or sellers. However, using email as an identification (I.D.) has a significant limitation considering the growing number of Web-based free email services. Some Internet auction sites provide user profiles. As we can easily guess, brand name products sell more than those of lesser well-known companies. The other popular approach is to require credit card information. Credit cards are one of the most popular means of payment in EC because of its universal acceptance and purchasing protection mechanism. Using credit cards gives buyers more protection than any other payment options, in case the seller turns out to be a malicious trading partner. A more sophisticated solution is using a reputation or rating mechanism. With such a reputation mechanism, buyers or sellers know how previous business partners think about the potential partner. This reputation system, if properly used, can reduce the incidence of fraud. Many popular auction sites employ all or a combination of the above-mentioned mechanisms. We have not addressed much the trust issue in our algorithm, nor have we implemented any specific mechanism to enhance trust in our system. If the proposed system is to be commercialized, enhancing trust should be one of the major improvements of the system.

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