Agents for Supporting Utility Tradeoff of Negotiation between Construction Contractor and Suppliers

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Abstract - This research describes a decision-support model that helps business bargainers explore negotiable options for the procurement in the construction industry. The proposed model is consisted of three software agents. One agent supports the contractors' decision by allowing them to input their negotiation preferences, and another supports the suppliers. Either of agents is not aware of the preferences of the other. The third agent plays the role of middle man who receives the proposals from both sides and search for optimal negotiation result in terms of total utility. Compared to the actual agreement specified in the two surveyed project contracts, the negotiation results suggested by the model increased the total utility by as high as 10% based on the preferences of human bargainers.

Keywords - E-commerce application; Genetic algorithm; Intelligent agent; Procurement negotiation

I. INTRODUCTION

Negotiation is commonly required in the procurement of construction materials to reach the final contractual agreement. In current practice, contractors bargain with suppliers according to bargainers' experiences instead of extensive exploration of negotiable options and bargainers' preferences. Consequently, bargainers often reach suboptimal agreements, and leave unclaimed value on the table as concluded by Raiffa [1].

While many factors lead bargainers to miss out on gains, falsely assuming fixed pies and the framing of the situation often cause parties to miss reaching mutually beneficial agreements. The challenge of negotiation arises, in part, from the fact that each side has private information about their own utility function but is ignorant of the other's values and strategies. Oliver's research [2] intends to help bargainers explore negotiable options by developing a decision-support computer system that consider, but not reveal, the utilities of both sides.

II. METHODOLOGY

Negotiation is a process for resolving conflicts between two or more parties. Mumpower [2] found that each negotiation party perceived the negotiable issues differently, and the perception of an issue might be represented by a function of judgment of utility, including weight, function forms, and organization of joint utility structure. Bazerman [3] divided the negotiation into two categories according to bargainers' attitudes: distribution (claiming the pie) and integration (enlarging the pie of available resources).

The distribution type of negotiation is a zero-sum game, i.e., one party's gain results in the other's loss. The strategy for such negotiation is to predict the bottom line of the other and present such an offer to maximize own benefit. Such a negotiation strategy usually results in a lower satisfaction level. On the other hand, the integration type promotes bargainers' cooperation. Because each bargainer has different preferences over each negotiable issue and option, the strategy is not to win on all issues, but to realize what issues the negotiators care most and make tradeoffs. Such negotiation usually results in a higher satisfaction level.

Decision-support research has focused on the design and development of tools for aiding bargainers in various domains such as Harris, Kraus, Wilkenfield, and Blake [4] that stresses model visualization capabilities, Kersten and Szpakowicz [5] that generates if-then production rules, and Matwin, Szapiro, and Haigh [6] that discovers rules for better negotiation.

A. Negotiable issues

A survey and follow-up interview by Dzeng et al. [7] were conducted to identify key issues that may arise during construction material procurement negotiations. Common options used for each issue, and the preferences of both contractors and suppliers regarding these options were also studied. The survey was sent out to 90 contractors in Taiwan in 2003, and received 55 responses (response rate=61.11%), within which 50 responses were valid (usable response rate= 55:6%). Key issues identified included: price, payment term, payment period, advance payment, resource provision, freightage, delivery, and opportunities for extended procurement, mass procurement, and future procurement.

These issues may be classified into four categories based on range of options available. The first category is price, for which options lie on a continuous spectrum.

The second category includes issues for which a limited number of commonly used options exist. For example, options for payment terms include: 'cash', '30-day check', '45-day check', and '60-day check'; for payment period options include 'on delivery', 'on completion of milestones' ,'on completion', 'monthly', and 'bi-weekly'; for advance payment options include '10', '15', '20', '25', and'30%'; for freightage options include 'included' and 'excluded', for delivery options

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include ‘single delivery’ ,‘multiple deliveries’, and ‘on-call delivery’.

The third category includes issues whose options are a list of items and quantities. For example, options for resource provision are a list of provided resources and quantities, and options for extended procurement opportunities are a list of additional procured items and their quantities.

The fourth category includes issues for which options are quantity related. For example, options for mass procurement opportunity are the maximum quantities procurable; and options for future procurement opportunity are possible future procurement quantities. The implied procured item for these issues is the item being negotiated on.

B. Modeling negotiation preferences

Negotiating strategies and the reaching of a satisfactory agreement are usually determined subjectively based on the experience and intuition of negotiators. Controlling the behaviors of artificial agents in such a humane way is difficult, and a systematic, quantitative model is necessary. This study uses the weighted payoff function (i.e. utility function) to represent the preferences of human negotiators regarding each option for each negotiable issue, and to model the aggression and concession in the negotiation.

Negotiation can be viewed as a process of seeking an agreement point in a multidimensional space. Each dimension corresponds to a negotiable issue, and can be discrete or real valued. Each issue may have several options. Each negotiating party values these options differently, and a multidimensional payoff function exists over the space of possible agreement points.

Suppose n negotiable issues exist, where an offer x can be represented using an array one-dimensional matrix [x1, x2…., xn],where xi denotes the chosen option for issue i. The payoff of a negotiator for a particular offer x can be represented as follows in Equation (1).

$$U(x)=\sum_{i=1}^{n}WiUi(xi) \qquad (1)$$

$U(x)$: total payoff of a negotiator for the chosen set ofoptions x;

$Ui(xi)$: issue payoff of a negotiator for the chosen option x_i for issue i;

W_i: weight of issue i for calculating negotiator payoff.

Based on this concept, contractor and supplier payoff functions are discussed below for the above four issue categories.

1) Category I issues

Figs. 1 and 2 illustrate conceptually typical payoff functions of contractors and suppliers for category I issue, which is price. Fig. 1 describes the preference of a typical contractor regarding price. As buyers, contractors have an acceptable price range [Amin, Amax], which they consider reasonable and are willing to accept. Additionally, contractors also have a desired price range [Dmin, Dmax], which falls within the acceptable price range. Starting from Amax (the highest acceptable price), contractor’s payoff increases with decreasing price. The payoff reaches the highest peak when the price reaches Dmax (the highest desired price).

Fig. 2 describes price preference of typical suppliers. Like a contractor, a supplier also has both an acceptable price range [A’min, A’max] and a desired price range [D’min , D’max], However, unlike a contractor, supplier payoff increases with increasing price. Excluding the possibility of fraud on the contractor’s side, the supplier may have no apparent upper boundary for the price they are willing to accept (A’max= ∞). Once again, the desired price range falls within the acceptable price range.

Fig. 3 shows both contractor and supplier payoff functions, where ΔD = [Dmin, D’max] is the maximum possible difference between the initial asking price of the contractor and the initial offering price of the supplier; i.e. space of starting points for the negotiation. ΔA = [A_{min}; A_{max}] represents the space of agreement points in the negotiation.

2) Category II issues

Fig. 4 illustrates five typical payoff functions for category II issues, including options for mass procurement, payment term, payment period, advance payment, freightage, and delivery. The options for each of these issues can be enumerated and their quantities are limited. Therefore, the respective payoff functions are discrete rather than continuous, as for category I. Type I payoff function shows that negotiator payoff positively correlates with issue options. For example, the contractor generally prefers longer payment term, in order to delay the payment as long as possible, and thus contractor’s payoff for ‘60-day check’ is greater than that of ‘cash’. Type II is a variation of type I and shows that the negotiator payoff tends to positively correlate with most issue options, but remains constant for some intermediate options. For example, some contractors may be indifferent between ‘30-day check’ and ‘45-day check’ for payment term. Type III shows that negotiator payoff tends to negatively correlate with issue options. For example, a supplier may prefer shorter payment term, and thus may have a smaller payoff for ‘60-day check’ than for ‘cash’. Similarly, type IV is a variation of type III.

Generally, contractor payoff is of type I or II for issue payment period and delivery; of type III or IV for issue payment term, advance payment, and freightage; and of type V for issue mass procurement opportunity. On the other hand, supplier payoff is of type III or IV for issue payment period, delivery; and mass procurement opportunity; of type I or II for issue payment term, advance payment, and freightage; and of type V for issue.

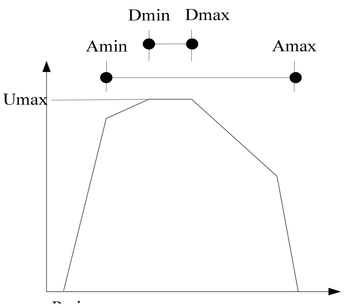

Fig.1 Contractor's payoff function for price.

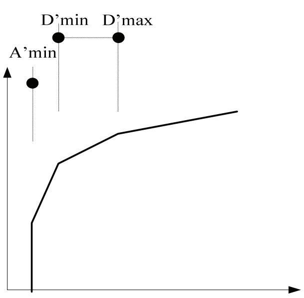

Fig.2 Supplier's payoff function for pric

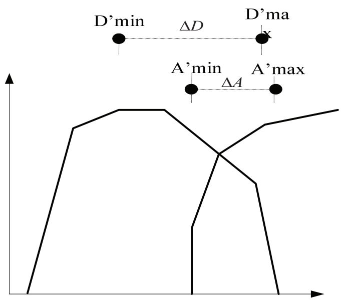

Fig.3 Price negotiation space for contractor and suppliers.

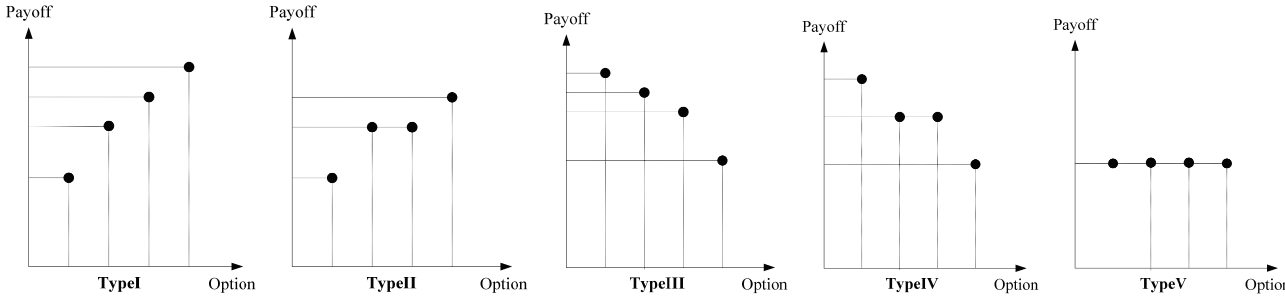

Fig. 4. Typical payoff functions for category II issues.

Nevertheless, many factors may affect both contractor and supplier payoff. For example, payment period options include 'on delivery', 'on completion of milestones', 'on completion', 'monthly', and 'bi-weekly'. Normally, a contractor will have a payoff of type III for payment period (i.e. prefer 'on completion' to any other options) to delay the payment as long as possible, maintain high level of reserved cash, and guarantee quality of work received.

However, the contractor payoff may be of type IV or V if the payment involved is small or the work duration is short.

3) Category III and IV issues

Category III issues, such as resource provision and procurement extension, require two inputs: a list of items and their quantities. Meanwhile, category IV issues, such as mass procurement opportunity and future procurement opportunity, although requiring only quantity as an input, can be treated in the same way as category III because the implied procured item for these issues is that being negotiated on.

This study uses estimated value as the unified measurement unit for procurement extension and resource provision, and expected value as the unit for mass procurement opportunity and future procurement opportunity, where the unit is a monetary value in both cases. These issues have no individual payoff functions because the options of these issues generally are offered by the contractor as presumptions, and cannot be changed by a supplier. Nevertheless, the monetary value of these issues may significantly influence supplier payoff for issues such as price. The influence is bigger than for a contractor because the options offered by the contractor normally use the capacity leeway of that contractor rather than squeezing capacity (i.e. offering additional procurement that was originally planned or additional resource capacity that is not used), but represent an opportunity for a supplier to gain extra contract value or achieve cost savings.

Each negotiation session between a contractor and a supplier involves three artificial agents, namely the contractor agent, supplier agent, and coordinator agent. Human bargainers control the contractor and supplier agents by setting payoff functions for each negotiable issue. The payoff function of the contractor agent differs from that of the supplier agent, and neither side knows the payoff functions of the others. However, the coordinator agent knows the payoff functions of both sides, and tries to identify an agreement point that meets the satisfaction levels and maximizes the joint payoff of both sides.

C. Decision-Support Model

The proposed decision-support model involves artificial agents playing the role of contractor and suppliers in a virtual supply chain. Agents bargain and find the most beneficial agreement using genetic algorithms. The buyer is the contractor, and the sellers are the suppliers providing materials to the contractor. All parties try to maximize individual payoff through negotiation.

The negotiation process is sequential for individual suppliers (i.e., making an offer and then waiting for a counter-offer), but may be parallel for the contractor negotiating with multiple suppliers (i.e., simultaneously making offers to multiple suppliers). Agents bargain by exchanging offers and counter-offers for the negotiable issues. Each negotiation session is free of time constraints.

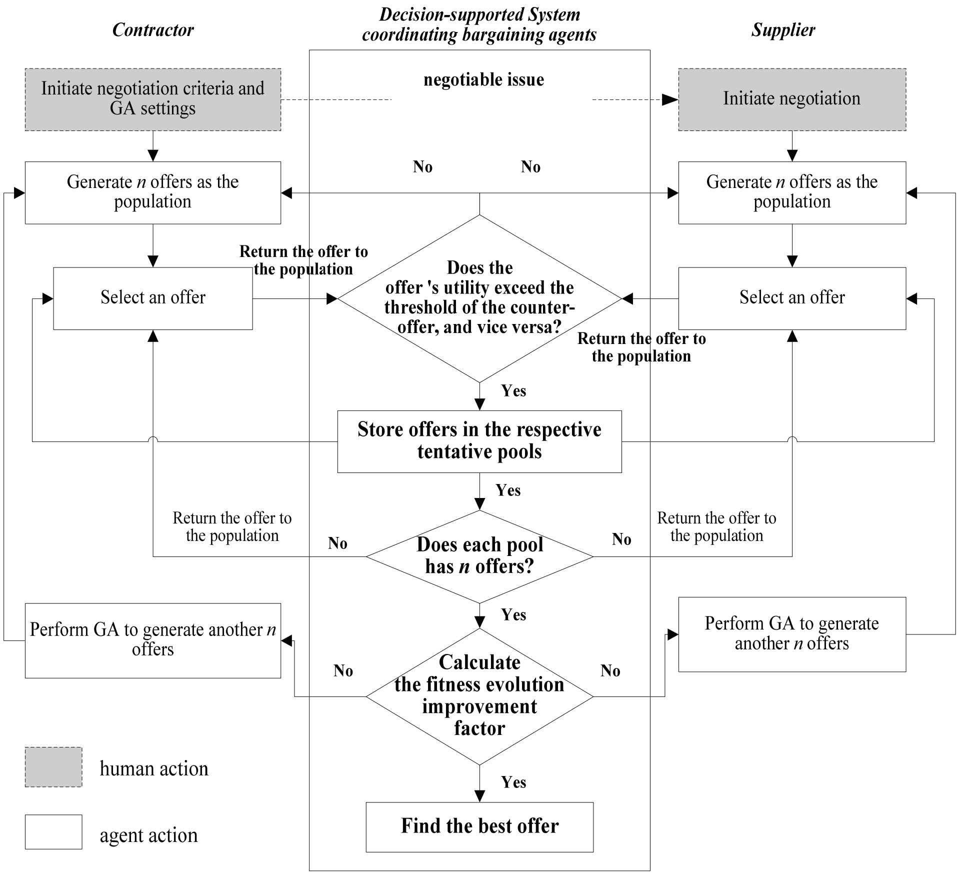

Fig. 5 Decision-support system for negotiation between the contractor and supplier

Each offer is represented as a gene, so that GA can apply genetic operators such as mutation and crossover to create a population of offers and evolve those offers to find the most beneficial one(s). Gene cell representation comprises two parts: the first cell is a threshold for accepting an offer, and the remaining cells represent the options associated with each negotiable issue. Offer i, a string of cells, can be represented by array [Ti, Oij], where Ti denotes the threshold for offer i, and Oij represents a list of options for each negotiable issue j of offer i. Threshold Ti equals the payoff of offer Oij to the offer maker.

The payoff of an offer i to a negotiator, representing negotiator satisfaction level with a particular offer, is defined as the weighted average of the payoff for each individual issue, as shown in Equation (2)

$$U(i) = \sum_{j=1}^{m} W_j U_j(O_{ij}) \qquad (2)$$

$U_j(O_{ij})$: individual payoff of option O_{ij} on issue j;
W_j: weight on issue j;
m: number of negotiable issues

Since the objective here is to find the offer that is most beneficial to both negotiating parties, joint payoff (the sum of the contractor's payoff and the supplier's payoff on an offer) is defined as the objective function. Because negotiation party attempts to maximize their individual payoff, the GA fitness function of the contractor or supplier is the individual payoff function.

Fig.5 presents the flowchart of the proposed decision-support system, which shows the actions of three agents, namely contractor, coordinator, and supplier agents. Boxes with solid lines denote activities performed by agents, while boxes with dashed lines indicate those performed by humans. To avoid confusion in the subsequent discussion, italic fonts refer to agents, while normal fonts refer to humans.

III. RESULTS

This section describes an experiment that compared the negotiation performances of human and the proposed system based on the joint payoff sum of final agreed options. A real five-story building project with its three procurement items, namely pre-mixed concrete, rebar, and rebar assembly was chosen for this purpose. The GA parameter values used for this experiment included population size = 50, crossover rate = 0.7, and mutation rate = 0.02. The threshold for the fitness improvement factor was set to be 5%.

Table 1 compares the negotiation outcomes of human (i.e., actual contract agreements) and agents for three suppliers (i.e., pre-mixed concrete, re-bar, and re-bar labor). Each set of outcomes includes the agreed unit price and options for the negotiable issues, as well as individual and joint payoffs. The table also lists in Column Improvement the percentage increase in payoffs for agent-based compared with human-based negotiation.

Agent-based negotiation always reached an agreement with higher joint payoff (from 2.0% more to 9.3% more) than human-based negotiation. Agent-based negotiation although may produce as high as 17.8% or 23.4% more for the contractor or supplier, it may also suggest an agreement that caused reduction in utility for some party as seen in Rebar Labor for the supplier.

This difference occurred because the human bargainers tried to reach a mutually acceptable agreement according to experience, while the agents tried to maximize the joint payoff through extensive search. Thus, agents are more motivated in finding the best agreement. However, as the experiment shows, the "best" agreements suggested by the system are not always feasible. Only those that produce higher joint payoffs without hurting either of individual payoffs will be accepted in reality.

The contractor must initiate the agent with a set of negotiation criteria (i.e., negotiable issues and their allowable options, weights and payoff functions) and GA settings (i.e., population size n, crossover rate c, mutation rate m, and threshold for fitness improvement factor g). Information on the negotiation criteria and GA settings is passed to Coordinator, but not to Supplier, except for the negotiable issues and allowable options, which are passed further to Supplier. The supplier must respond to this message by determining acceptable options, weight, and payoff function for each negotiable issue.

Table 1
Experiment result

Item			Final Outcomes Human	Agent	Improvement
concrete	Agreed options	Unit price	$47	$43	
		Payment term	*60-day check*	*30-day check*	
		Payment period	*monthly*	*on-delivery*	
		Delivery	*on-call*	*on-call*	
		Freightage	*included*	*included*	
	Payoffs	Contractor	91	90	-1.0%
		Supplier	64	68	+6.3%
		Joint	155	158	+2.0%
Rebar	Agreed options	Unit price	$272	$253	
		Payment term	*60-day check*	*30-day check*	
		Payment period	*monthly*	*monthly*	
		Delivery	*single*	*multiple*	
		Freightage	*included*	*excluded*	
	Payoffs	Contractor	86	86	+0%
		Supplier	64	79	+23.4%
		Joint	151	165	+9.3%
Rebar labor	Agreed options	Unit price	$108	$108	
		Payment term	*cash*	*30-day check*	
		Payment period	*monthly*	*on delivery*	
		Delivery	*multiple*	*on-call*	
	Payoffs	Contractor	73	86	17.8%
		Supplier	64	54	-15.6%
		Joint	137	140	2.2%

IV. CONCLUSION

The remedy to this problem presented here was to choose the agent-suggested 10 best offers, and present only those offers with individual payoffs equal to or higher than those of human-based negotiation. Human found acceptable agreements from the presented ones in most cases. When none of the presented agreements was acceptable, the human might adjust some terms to reflect their concerns.

The improvement in joint payoff was smaller than expected. This phenomenon occurred because the number of negotiable issues and options were limited, and human bargainers could reach good agreement depending on years of experience. Nevertheless, the experiments also demonstrated that the proposed system occasionally might help human "leave less money on the table", achieving improvements of as much as 9.3% of payoff, as in the negotiation with re-bar supplier for Project B (Table 1).

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