EXPLORING THE MONEY LEFT ON TABLE FOR CONSTRUCTION PROCUREMENT NEGOTIATION

Ren-Jye Dzeng, Associate Professor
Department of Civil Engineering, National Chiao-Tung University, Hsinchu 30030, Taiwan
rjdzeng@mail.nctu.edu.tw

Abstract: Most contractors negotiate with suppliers for their construction procurement according to negotiators' experiences instead of extensive exploration of negotiable options and negotiators' preferences. Consequently, negotiators often reach suboptimal agreements, and leave money on the table. This research developed an agent-based computer system that find optimal agreements using the genetic algorithm, compared the results with the actual contractual agreements, and determine the "money" left on the table in the traditional construction negotiation.

Keywords: intelligent agent, genetic algorithm, e-commerce, artificial intelligence, construction management

1. INTRODUCTION

Negotiation is commonly required in the procurement of construction materials to reach the final contractual agreement. For a construction procurement item, a general contractor typically solicits several price quotations from suppliers, considers the suppliers' performance, evaluates those quotations, and narrows down a few prospective suppliers. Subsequent process often involves formal or informal negotiations between the general contractor and the prospective suppliers to finalize the price and other contractual terms (e.g., payment by 30-day check or 60-day check, and payment calculated monthly or at completion).

Nevertheless, a general contractor needs to limit the number of prospective suppliers to negotiate with and the number of negotiation meetings because of the time and man-hours involved. As a result, the negotiation agreement is usually reached depending on experience instead of extensive exploration of negotiable options and preferences of negotiating parties. As concluded by Raiffa [16], even in simple negotiations, people often reach suboptimal agreements, thereby "leaving money on the table". 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. [14]

This research developed an agent-based computer system that find optimal agreements using the genetic algorithm, compared the results with the actual contractual agreements, and determine the "money" left on the table in the typical construction negotiation. Negotiators involved in three procurement items (i.e., pre-mixed concrete, rebar, and rebar laborer) of two plant-office complex projects participated the experiments.

2. LITERATURE REVIEW

Negotiation is a process for resolving conflicts between two or more parties [2]. Ali [1] investigated the factors that suppliers might consider when submitting a bid to a general contractor, including prompt payment habit, reputation for shopping after contract award, experience in building similar projects, efforts in planning and supervision, financial capacity, reputation for finishing projects on time, other work opportunity, and chance to get job of the contractor, past experience with the contractor, clarity of work's specifications, terms of general contract, construction schedule, and construction methods used. Many of these factors (e.g., reputation for shopping after contract award and experience in building similar projects of the contractor), despite being important for preparing the bid proposal, are unlikely to appear as an issue in the negotiation process.

Mumpower [12] found that each negotiating 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. Decision-support research has focused on the design and development of tools for aiding negotiators in various domains such as Genie [8] that stresses model visualization capabilities, NEGOPLAN [10] that generates if-then production rules, and GBML [11] that discovers rules for better negotiations.

Software agents are also employed to facilitate negotiation. Software agents are computer programs that exhibit a certain degree of autonomy. They are continuously active and interact with other systems

on behalf of the user [4]. Nwana [13] divided agents into collaborative agents, learning agents, interface agents, and smart agents. Brenner [5] divided agents into three categories according to their tasks: information agents who search, filter, analyze, and present information; cooperation agents who solve complex problems by cooperating with other agents, humans, or external resources; and transaction agents who execute and monitor transactions.

Snadholm and Lesser [17] found that cooperative agents often exist and perform tasks inside an enterprise such as production planning and meeting scheduling. A competitive agent will not give in unless it can receive comparable compensation during negotiation because it cares only its own benefit and is least concerned with joint benefit. However, such competitive style prevents disclosure of individual preferences and often results in individual loss of benefit. Many electronic commerce (EC) web sites such as OnSale [15], eBay's Auction Web [7], Kasbah [9], and Auction Bot [3] also offer agents that help on-line negotiation on price. For example, Kasbah adopts the distribution type of negotiation and allows users to define their own agents with buying strategies (i.e., anxious, cool-head and frugal), selling strategies (i.e., anxious, cool-head and greedy), and initialization parameters (e.g., asking price, acceptable price, and deadline). T@T [18], in addition to price, allows both buyer and sellers to customize their agents and negotiate on warranty, delivery time and method, service plan, return policy, and free bonus. No agents have been developed to specifically help negotiation of construction procurement between contractor and suppliers.

This research chooses the agent-based approach, and assumes an integration type of negotiation; i.e., enlarging the pie of available resources. Each agent has its own preferences and negotiates with each other through collaboration. However, to be realistic, a negotiating agent is not aware of the preferences of the other, and is communicating through an intermediate coordinator agent.

3. NEGOTIATION AGREEMENT POINTS

In practice, issues to be negotiated are determined at the beginning of negotiations, but new issues sometimes may arise during negotiations. The contractor proposes desired options for the negotiable issues, and the supplier proposes a price according to these options. The proposed price may be continuously lowered during the negotiations. The supplier may also request to modify terms or to include new issues to offset price decreases. The negotiation ends when both parties agree on the options and price.

Dzeng and Lin [18] have conducted a survey to identify key negotiable issues that may arise during construction material procurement negotiations. 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 according to the 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 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.

Among the issues identified, only the first and second categories are considered negotiable in this study. Issues of the third and fourth categories are not considered because they mainly arise in a negotiation out of capacity leeway of a contractor and are wholly determined by the contractor. For example, a contractor only offers an opportunity for extended procurement to a supplier when there is still extended procurement that has not been tendered. It is uncommon for a supplier to make a contractor to squeeze out new procurement during the negotiation. As a result, these issues are treated as non-negotiable issues and are determined solely by a contractor.

The non-negotiable issues, although cannot be counter-offered by a supplier, may affect a supplier’s quoted price. Because these issues involve uncertainty, they are represented by estimated

expected monetary values in this research.

3. OPTIMAL NEGOTIATION AGREEMENT

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. Payoff of an option with respect to a negotiator represents the negotiator's preference (or utility) over the option. This study uses the weighted payoff function to measure the goodness of a negotiation agreement.

Suppose n negotiable issues exist, where an offer x can be represented using an array $[x_1, x_2, \ldots, x_n]$, where x_i denotes the chosen option for issue i. The payoff of a negotiator for a particular offer x can be represented as follows.

$$U(x) = \sum_{i=1}^{n} W_i U_i(x_i) \qquad (1)$$

$U(x)$: total payoff of a negotiator for the chosen set of options x;
$U_i(x_i)$: issue payoff of a negotiator for the chosen option x_i for issue i;
W_i: weight of issue i for calculating negotiator payoff.

According to this concept, simplified, generalized contractor and supplier payoff functions used in this study are discussed below for the aforementioned two categories of negotiable issues.

Negotiator payoff may 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". Negotiators may also feel indifferent to some intermediate options. For example, some contractors may be indifferent to a payment term of "30-day check" or "45-day check". Similarly, a negotiator's payoff may also 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". Of course, some suppliers may also feel indifferent to the length of *payment term*.

4. System Description

The system comprises three agents, namely *Contractor*, *Supplier*, and *Coordinator*. The human 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 human supplier must respond to this message by determining acceptable options, weight, and payoff function for each negotiable issue.

Contractor and *Supplier* have similar objectives; i.e., to generate an offer that is acceptable to its own criteria and has payoff higher than the offer proposed by the counter part through a continuously random selection process, and evolve the offer to find the best one through GA. Take *Contractor* as an example, the first step is to generate n offers as its population. Each offer includes an option for each negotiable issue and a threshold T, which equals the corresponding payoff of the option according to the payoff function of the contractor. The threshold represents the satisfaction level of the contractor with the offer. The second step involves randomly selecting an offer from the population and submitting it to *Coordinator*, who at this time also receives an offer from *Supplier*. If the offer of *Contractor* provides *Supplier* with a payoff higher than that from the *Supplier* offer, and *Supplier* offer provides *Contractor* a payoff higher than the payoff of the *Contractor* offer, both offers are saved in their respective tentative pools. Otherwise, *Coordinator* passes the offer back to *Contractor* and *Supplier* and asks them to select another offer. This process continues until *Coordinator* has *n Contractor* offers and *n Supplier* offers. The total of *2n* offers are used to calculate the fitness evolution improvement factor g. If g is smaller than the pre-determined threshold, the search has reached a convergence, and *Coordinator* presents the offer with the highest sum of payoff of both contractor and supplier as the final result. Otherwise, *Coordinator* requests both *Contractor* and *Supplier* to generate another generation of offer populations. Through generations of evolution, when g is below the threshold, most offers in the population already have fitness scores approaching the best offer. Thus, further evolution achieves insignificant improvement, and so evolution can stop.

5. EXPERIMENT METHODOLOGY

This study conducted experiments to find the payoff left on the table of construction negotiating parties. Three procurement items, namely pre-mixed concrete, rebar, and rebar assembly, of two projects A and B were selected for the experiments. Both projects involved an office-plant complex. Project A is a $US 7.77 millions project that has five stories plus one underground story, while Project B is a $US 22.79

millions project that has five stories plus two underground stories. The negotiators originally involved in the contracts were invited to assign the utility weights for the relevant negotiable issues and options in C-Negotiator. The negotiators included the section manager of the participating contractor, and the owner, president or vice president of the subcontractors, with from 9 to 21 years of procurement experience.

The actual contractual agreement was taken as the outcome of human negotiations while the agreement suggested by the C-Negotiators was assumed to be theoretically optimal outcome. Because human negotiators may not accept the best agreement suggested by C-Negotiators, the following best agreement that was acceptable to human negotiators was the actual optimal outcome.

The parameter values used for GA were based on the suggestions proposed by DeJong, and included population size = 50, crossover rate = 0.7, and mutation rate = 0.02. The threshold for the fitness improvement factor was set to 5%. A virtual project was also used to help participants familiarize themselves with the system before the experiments began.

6. EXPERIMENT RESULTS

Table 1 compares the negotiation outcomes of contractual agreement (i.e., human negotiation), theoretical optimal agreement (i.e., the best agreement found by C-Negotiators), and the practical optimal (i.e., the agreement chosen by negotiators from the best 10 agreements found by C-Negotiators) for three suppliers, PMC (pre-mixed concrete), REB (re-bar), and RLB (re-bar labor) of both projects. Each set of outcomes includes a joint payoff as well as contractor's and supplier's individual payoffs.

C-negotiators always reached an agreement with higher joint payoff (from 1.1% more to 9.8% more) than human-based negotiation. This difference occurred because the human negotiators 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.

The improvement in joint payoff was smaller than expected. This phenomenon occurred because the number of negotiable issues and options were limited, and human negotiators could reach good agreement depending on years of experience. Nevertheless, the experiments also demonstrated that C-Negotiator occasionally might help negotiators “leave less money on the table”, achieving improvements of as much as 9.8% of payoff, as in the negotiation with re-bar supplier for Project B (Table 1).

Agent-based negotiation does not always reach an agreement with higher contractor payoff or supplier payoff than human-based negotiation. While agent-based negotiation attempts to find the agreement with the highest joint payoff, it may also indirectly redistribute the payoff between contractor and supplier. Therefore, one may not accept the agent-suggested best agreement if his/her payoff is lower than the payoff of human-based negotiation. 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. Negotiators found acceptable agreements from the presented ones in most cases. When none of the presented agreements was acceptable, the negotiators might adjust some terms to reflect their concerns.

Table 1 Negotiation outcomes of the experiments

		Con-tractual	Theo-rectical Optimal	Improve-ment%	Practical Optimal	Improve-ment%
			Project-A			
PMC	**Joint**	**146.0**	**147.5**	**1.1%**	**147.0**	**0.7%**
	Contractor	72.0	68.0	-5.5%	70.0	-2.7%
	Supplier	74.0	79.5	7.5%	77.0	4.1%
REB	**Joint**	**153.9**	**165.0**	**7.3%**	**165.0**	**7.3%**
	Contractor	85.3	92.5	8.5%	92.5	8.5%
	Supplier	68.6	72.5	5.7%	72.5	5.7%
RLB	**Joint**	**146.7**	**149.0**	**1.5%**	**149.0**	**1.5%**
	Contractor	72.0	87.0	20.8%	75.0	-4.2%
	Supplier	74.7	62.0	-17.0%	74.7	-1.0%
			Project-B			
PMC	**Joint**	**154.3**	**158.0**	**2.4%**	**157.8**	**2.2%**
	Contractor	90.7	84.0	-7.4%	90.3	-0.5%
	Supplier	63.6	74.0	16.4%	67.5	6.1%
REB	**Joint**	**150.6**	**165.4**	**9.8%**	**165.4**	**9.8%**
	Contractor	86.3	86.4	0.2%	86.4	0.2%
	Supplier	64.4	79.0	22.8%	79.0	22.8%
RLB	**Joint**	**137.0**	**139.5**	**1.8%**	**138.0**	**0.7%**
	Contractor	73.0	85.5	17.1%	75.0	2.7%
	Supplier	64.0	54.0	-15.6%	63.0	-1.6%

Discussion

Figures 1-3 compares the improvement of joint payoff, contractor's payoff, and supplier's payoff of C-Negotiators' suggested best agreement (theoretical best) and the agreement actually chosen by negotiators (actual best). In the Y-axis, the first letter represents the project (e.g., A- for Project A) and the following three letters represent the contract (e.g., RLB for rebar labor). Figure 1 shows that the theoretical best improves the joint payoff by approximately from 1% to 10%. However, negotiators may not always agree to those values, as shown by B-RLB, B-PMC, and A-PMC.

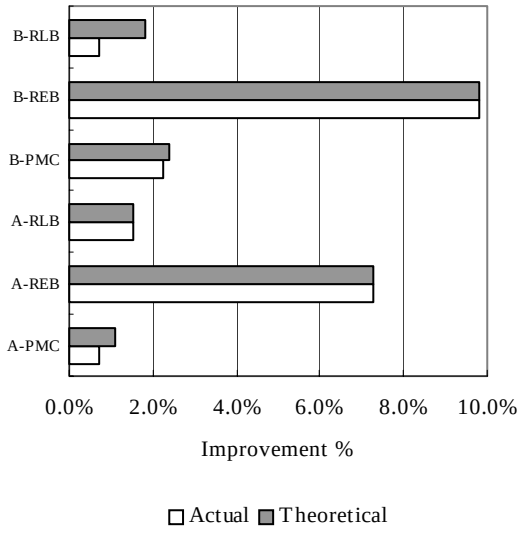

Figure 1 C-Negotiators' improvement on the joint payoff

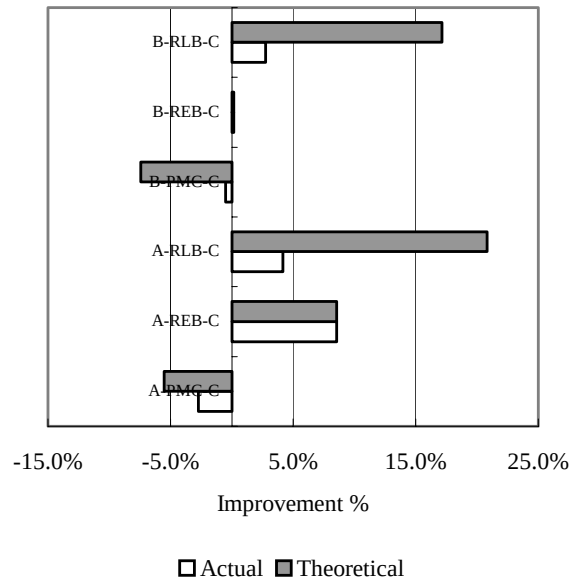

Figure 2 C-Negotiators' improvement on contractor's payoff

Figures 2 and 3 show that, when C-Negotiators was improving the joint payoffs, the improvement on both contractor's and supplier's payoffs was not guaranteed. This also resulted in greater difference in the payoff improvements of actual best and theoretical agreements, as shown by B-RLB, B-PMC, A-RLB, and A-PMC in Figures 2 and 3. In other words, when C-Negotiators suggest the best agreement, negotiators will accept only if the agreement results in better or equal payoff than the contractual agreement, and the proportion of contractor's and supplier's payoff in the joint payoff did not considerably deviate from that of the contractual agreement.

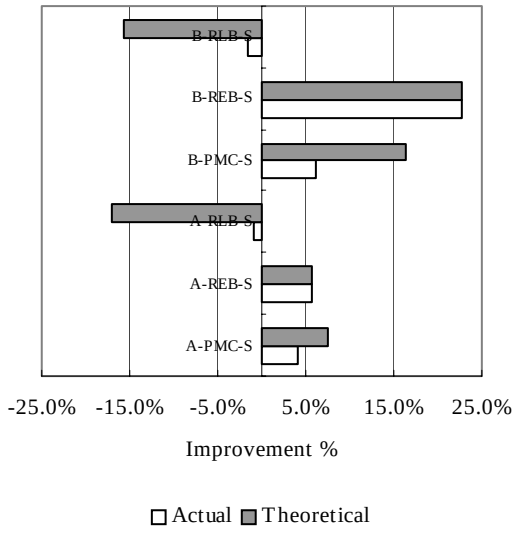

Figure 3 C-Negotiators' improvement on supplier's payoff

However, unlike we have hindsight in these experiments regarding the contractual agreements, in actual negotiation, no one knows the contractual agreement at the time of negotiation. Therefore, even though C-Negotiator's algorithm can be adapted to keep the proportion to accommodate the bargaining power issue, appropriate proportion is hard to determine. Past contracts may be a clue to discovering such a proportion. The future direction of this research will focus on addressing this problem.

Acknowledgement

The author would like to thank his graduate student, Y.C. Lin, for the implementation of C-Negotiators, and the National Science Council, Taiwan, for financially supporting this work under Contract No. NSC-92-2211-E009-064.

REFERENCES

[1] Ali, A.S. Subconstruction bidding decision, *Journal of Construction Engineering and Management* 124(2), 101-106, 1998.

[2] Anson, R.G. and M.T. Jelassi, A development framework for computer-supported conflict resolution, *European Journal of Operational Research* 46, pp.181-199, 1990.

[3] Auction Bot, http://auction.eecs.umich.edu/, last updated, 2001.

[4] Bradshaw, J.M., *Software Agents*, AAAI Press, Menlo Park, California, 1997.

[5] Brenner, W., Zarnekow, R. and Wittig, H. *Intelligent Software Agents: Foundations and Applications*, Springer, New York, 1998.

[6] Dzeng, R.J. and Lin, Y.C. " Intelligent agents for supporting construction procurement negotiation", *Expert Systems with Applications*, 27(1), August, 2004.

[7] eBay, http://www.ebay.com/, last updated, 2004.

[8] Harris, M., Kraus, S., Wilkenfield, J. and Blake, E. A decision support system for generalized negotiations, in *Proc. of 13th Annual Meeting on Cognitive Science*, pp.382-387, 1991.

[9] Kasbah, https://kasbah.media.mit.edu/cgi-bin/KasbahLogin , last visited, 2004.

[10] Kersten, G. and Szpakowicz, S. Rule-based formalism and preference representation: an extension of NEGOPLAN, *European Journal of Operations Research* 45, pp.309-323, 1990.

[11] Matwin, S., Szapiro, T. and Haigh, K. Genetic algorithms approach to a negotiation support system, *IEEE Transactions on Systems, Man, and Cybernetics* 21(1), 102-114, 1991.

[12] Mumpower, J.L. The judgment policies of negotiators and the structure of negotiation problems, *Management Science* 37(10), pp.1304-1324, 1991.

[13] Nwana, H.S. Software agents: an overview, *Knowledge Engineering Review*, 11(3), 205-244, 1996

[14] Oliver, J.R. A machine-learning approach to automated negotiation and prospects for electronic commerce, *Journal of Management Information Systems* 13(3), pp. 83-112, 1996.

[15] OnSale, http://www.onsale.com/, last updated, 2004.

[16] Raiffa, H. *The Art and Science of Negotiation*, Harvard University Press, Cambridge, MA, 1982.

[17] Snadholm, T. and Lesser, V.R. On automated contracting in multi-enterprise manufacturing, in *Proc. of Improving Manufacturing Performance in a Distributed Enterprise: Advanced Systems and Tools*, Edinburgh, Scotland, pp. 33-42, 1995

[18] T@T, http://ecommerce.media.mit.edu/tete-a-tete/, last updated, 2004.