Simulating Reverse Auction Bidding of Construction Contracts

Dr. Khaled Nassar
University of Sharjah
Sharjah, UAE

Simulation using agents has gained a wide prominence in a wide area of applications. In particular agent-based negotiation is concerned with simulating the behavior of parties interacting with each other to reach an agreement. In this paper, a construction-specific model for negotiation between agents representing contractors in a Reverse Auction Bid (RAB) is presented. RAB is a fairly new electronic bidding model where contractors bid on a particular contract by iteratively lowering their bids. We specifically present a model that can deal with many-parties, single issue, multiple-encounter negotiations. A computerized system is developed to test the model. An example of the system is presented for clarification.

Keywords: Teaching Evaluation, Student Course Evaluation, Relational Databases Autonomous agents, construction contracts, reverse auction bidding, negotiation

Introduction

Negotiation is a central characteristic of the construction process. There are a number of different negotiation theories and techniques that can be used in a variety of situations (Barcharach and Newnham 2000, Bell 2001, Bacharach and Lawler1981, Anumba and Newnham 2000, Ren et al 2003). In particular, negotiation involving construction contracts are usually of a type called service-oriented negotiations (Zeuthen 1975). Service-oriented negotiations are a type of negotiation where the purpose is to reach an agreement about the provision of a service by one side for another. Nevertheless, all types of negotiations entail two separate but interconnected elements: a rational decision making element and a psychological element. In order to improve the outcomes of negotiations, automated negotiation using autonomous agents have recently become one of the fundamental decision models studied. The main perceived benefit of using agent-based negotiation technology is the removal of the emotional component of the negotiations that so often result in less than Pareto-optimal agreements. A Pareto efficient outcome is one in which there is no other agreement that would result in both parties being better off. If there is an outcome that would have made both better off, the decision reached is not Pareto-optimal. Pareto-optimal agreements usually are attainable when there are options to be negotiated in the terms of the agreement.

In order to investigate the properties of RAB, an autonomous bidding model is developed in this paper. The model aims at investigating basic properties of the RAB model. The remainder of this paper is organized as follows; first, an introduction to negotiation is offered. This is followed by a discussion of Reverse Auction Bidding as a new method of construction bidding and differences between RAB and traditional bidding are outlined. Next, the developed model is presented and example simulations of autonomous bidding are described. Finally, conclusions are drawn and recommendations for future work are presented.

Negotiation, Bargaining and Pareto Efficiency

Although sometime used synonymously, there is a difference between negotiation and bargaining. The main difference is in the presence of options to offer to the other side. When two parties are negotiating an agreement in the absence of options that each part can offer the other, the negotiation often breaks down into a haggling or a bargaining exercise. In bargaining, the emphasis is on the social and psychological factors. The party that masters the skills of utilizing personal and psychological factors as well as an understanding of the other party's position will obviously be advantageous. Negotiating parties mainly just try to drive each others price downward or upward by giving superfluous reasons similar to what happens in a traditional market. On the other hand, when the negotiating parties have the ability to generate options to the other party, the process becomes more complex. In addition, to the psychological and social factors, the ability to analyze the options becomes of critical importance. Since the options will usually carry different values to the different parties, the ability to choose the options that maximize the return to both parties becomes extremely important. This even happens in traditional markets where buyers may offer to buy more of the item for a lower price, or where a seller may offer to deliver the item being negotiated for free. The parties have to negotiate those options in addition to the terms of the initial contract to ensure an optimal agreement.

Therefore the goal of negotiations is to be as "Pareto Efficient" as possible. A Pareto efficient outcome is one in which there is no other agreement that would result in both parties being better off. If there is an outcome that would have made both better off, the decision reached is not Pareto efficient. Stated differently, an agreement is "Pareto Efficient" if one party cannot do better without some other party doing worse. Collectively, negotiators leave "money on the table" when they settle for a Pareto inefficient agreement. Negotiators should aim at gaining Pareto efficient agreements, finding all joint gains, and not leaving money on the table. If all the options are known in advance and a matrix can be put together that contains the expected returns and value for both parties involved then the problem of finding an optimum agreement can be formulated as a game theory. In another formulation, the problem of finding a Pareto optimal agreement may be formulated as an assignment problem where the objective is to find the combination of options that maximizes the returns to both parties. In order to make negotiations more effective, several researchers have looked at various techniques, such as devising new negotiation mechanisms such as autonomous negotiation. On the other, new paradigms of negotiations have been developed in line with the revolution in communications and the internet such as Reverse auction bidding, which is explained next.

Reverse auction bidding

Autonomous agents have been studies now for quite a while in the realm of business and e-commerce. Only recently has the interest started to catch up in the construction industry. The interest in autonomous agent negotiations will increase with the increased use of ecommerce techniques, procurement and especially with the advent of Reverse Auction Bidding (RAB).The use of reverse auction bidding by owners of various sizes, especially large commercial owners such as superstores, has resulted in a completely new and unique manner of doing business. Some owners believe that RAB is an effective way to reduce costs, while the majority of contractors remain doubtful about the true cost and effectiveness of RAB. The concept behind reverse auction bidding is to let contractors compete with one another to lower their bids for a certain project until a pre-set time or other cut-off. A typical format for RAB starts after potential contractors obtain all contract documents electronically. Usually, the identities of bidders are kept confidential during the bidding, although a number of professional have suggested otherwise. The interesting part of RAB that is often neglected is that every time a low price is submitted, a new bidding horizon in terms of additional time allowed is provided to contractors (including the previous lowest bidder) so that their bids can be revised. After a certain amount of time has lapsed without any lower bids being placed, the lowest price is determined and all bidders are notified. Therefore, in order to assess effectiveness of reverse auction bidding, an electronic model was developed. The model is described next.

An RAB Model for Construction Projects

The model described here can be used to represent the processes of reverse auction bidding in the construction market. The model is consequently used to test the process of reverse auction bidding in construction. The model is based on the concept that contractors involved in RAB usually do not have any motivation to start bidding with their lowest bid. At the same time each contractor will have a minimum acceptable bid that he/she does not want to go below. Therefore the RAB will start with each contractor placing a bid that is higher than his/her lowest bid in order to gauge the competition. The rational is that the contractor does not want to leave any "money on the table". This is not unlike traditional bidding when the contractor gauges his competition so that to minimize the difference between his/her bid and next lowest bidder. However in RAB, the contractor gets several chance/iterations to accomplish this, while in traditional bidding there is only that single bid. Although the minimum acceptable bid is determined a-priori, there is still room to go below that minimum, e.g. by reconsidering the acceptable profit or through further negotiations with the subcontractors.

Therefore that minimum acceptable bid may change depending on the bidding conditions and the competition. Each contractor will then lower his bid incrementally based on how the competing contractors lower their bid. In this paper, the rate at which each contractor reduces his/her bid is called the "bidding gradient" and it describes the speed at which a contractor reduced the bid and the points in time where the bids are placed. A sample bid gradient is shown in Figure 1. The contractors will then reduce their bids up to their minimum acceptable bids, beyond which contractors may re-evaluate their markup expectation or their marginal costs. Unlike regular online auctions, in RAB, the bid remains open for a specified amount of time each time a lower bid is placed. This allows the contractors to re-evaluate their bids according and also allows them to consider lowering their initially anticipated profit (in terms of the original percentage markup) or even perhaps revises their marginal costs. The pressure to reduce their bids below the minimum acceptable bid depends on the project complexity as well as the market demands for the contractor. The more the contractor is certain about the project the more he/she is willing to reduce their bids. Similarly the greater the market pressures on the contractor to acquire a new contract the lower the new "rock bottom" bid.

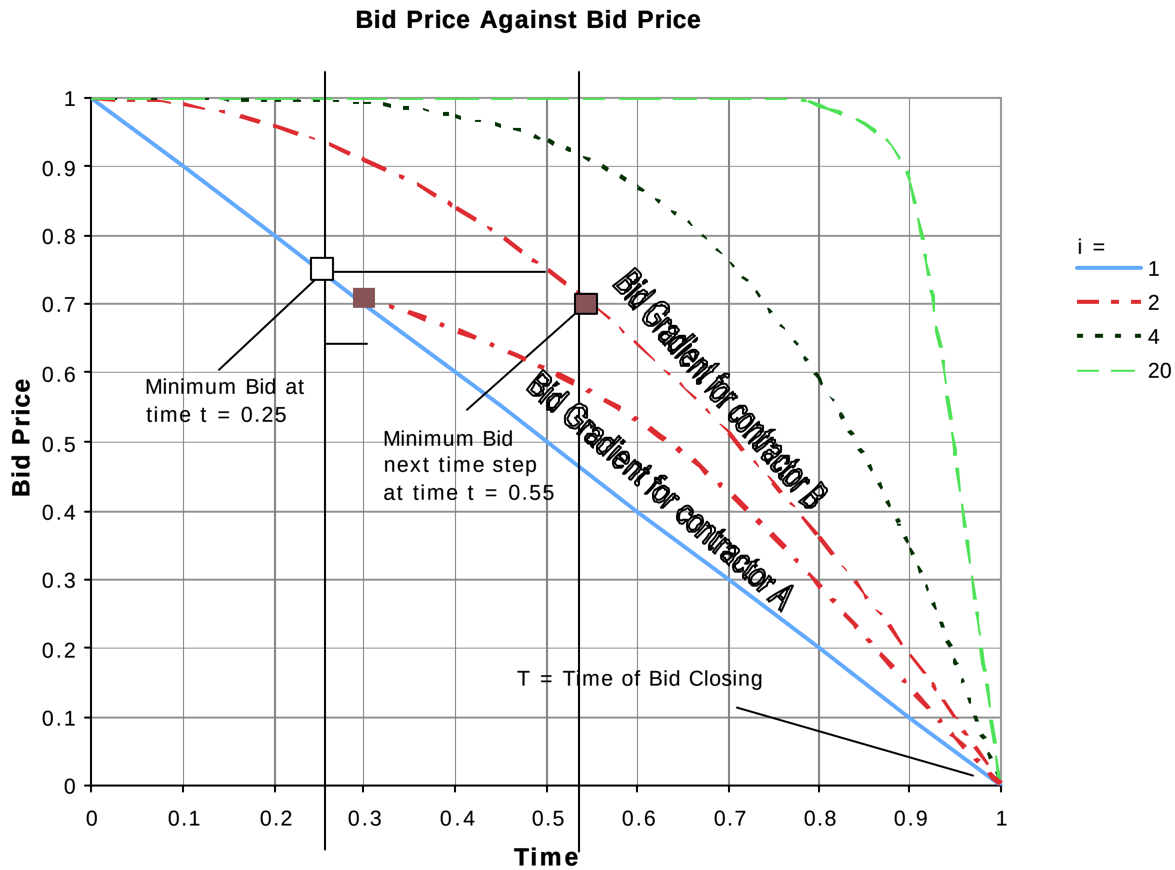

Figure 1: A sample bid gradient

Oligopoly theory also suggests that it may be harder for firms to reach a non-cooperative solution the more dissimilar their costs. The model therefore assumes that there are *n* contractors, (*n = 1, 2, …,N*) who have qualified to bid for the project. Each contractor *n* will place a bid on the project at time *t*, x^t_n. Therefore, contractors start by placing an initial bid that is above their intended minimum acceptable bid m_n. The bid at each time t depends on the current lowest bid $Curm = \min\left(x_1^{t-1}, x_2^{t-1}, x_n^{t-1}, .. x_N^{t-1}\right)$, and is given by,

$$x_n^t = G_n\left(Curm_t, t, m_n, Botm_t\right) \qquad (1)$$

G_n is the bidding gradient function for contractor *n*, $Botm_t$ is the "rock bottom" biding price that results from the contractor re-evaluating his/her bid. The amount that a contractor may reduce the minimum acceptable bid depends on the marker pressures as well as the Complexity of the project and can be modeled as

$$Botm_t = Curm_t \times \left(1 - \frac{1}{p \times C}\right) \qquad (2)$$

p is the market pressure index, C is the project definition index and t is the bid time. The value p→ 1 as the project complexity decreases, while the value of C → 1 as the market pressures decrease. If the contactors bid is higher than the current bid, i.e. $x_n^t >= Curm_t$ then p and $C = 1$ and $Botm_t = Curm_t$. At this point the contractor's bid is dependant on his/her minimum acceptable bid m_n as well as the current minimum bid. It is logical to assume that the contractor would move along the bid gradient in steps equal to the distance from the current minimum bid. So the bid gradient for contractor n takes the following form,

$$G_n^t = I_n \times \left[T - \left(\frac{t}{T} \right)^i \right] + m_n \qquad (3)$$

where I_n is the initial bid for contractor n and T is the bid closing time, i is an even number and can be considered the stiffness index for the contractor which represents the speed at which the contractor is lowering his price, i.e.

$$\frac{dG_n^t}{dt} = i \times \left(\frac{t}{T} \right)^{i-1} \qquad (4)$$

Notice that the higher the gradient stiffness the faster the contractor is to willing to lower his/her bid price. Using this simple model, a simulation of an autonomous reverse auction bid can be conducted to evaluate various aspects of the bidding process. This is explained in the next section.

Example

A simulation of autonomous agents involved in a reverse auction bid was conducted using the model described above. The simulation involved 3 contractors, each with a different bid gradient function as well as different minimum acceptable bids. Also, each contractor has different perceived market pressures and project complexities. Just as in a RAB, the bid opening and initial closing times are predefined before hand and announced to all contractors. Each contractor is arbitrarily assigned a specific bid gradient, stiffness, market pressure and perceived project complexity values. The bid starts with a single bid from one of the contractors, after which time is incremented by the predefined time step. Next, the contractor bidding gradient determines his/her bid decision as well as the amount of bid. If the current minimum bid falls below any of the contractor's minimum acceptable bid, then the bid reevaluation stage is instantiated. The contractor generates the revaluated bid based on (2) above. Then the bid gradient will determine again the bid decision and the bid amount. Finally, the bid closes after advancing the simulation clock passed the reevaluation period without any bids being placed.

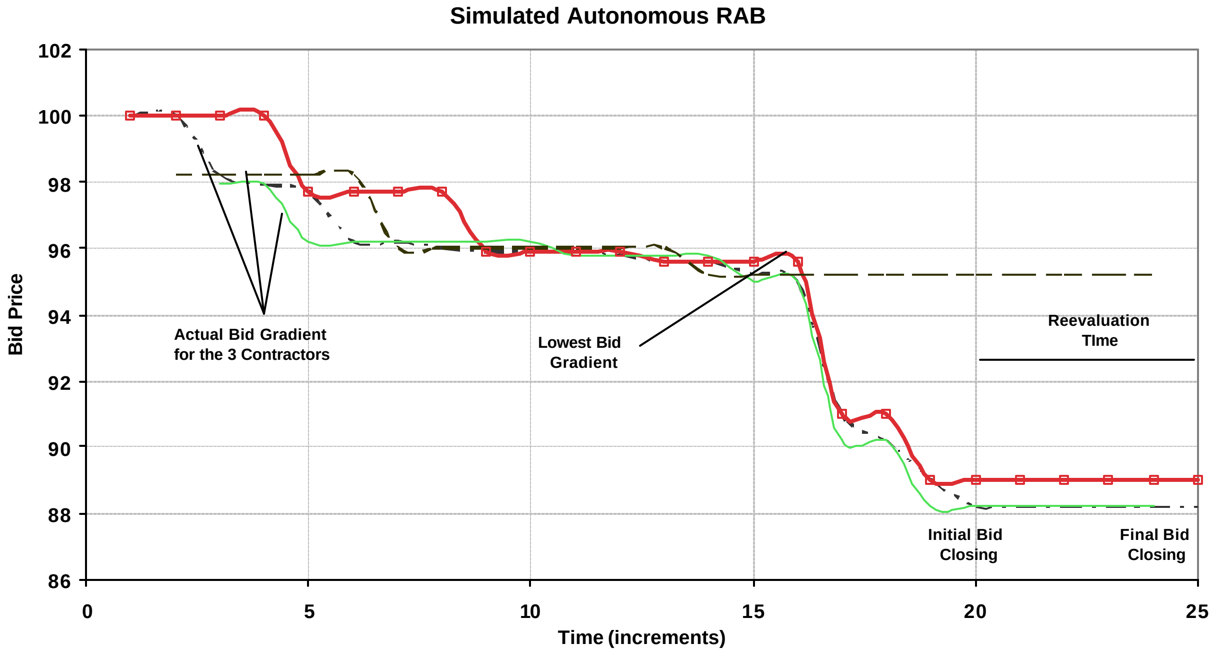

Figure 2: The simulated bid

Figure 2 shows the simulated bid profile for the three contractors as well the minimum bid profile. Notice, that in a RAB, contractors usually engage in bid gaming by placing artificially high bid prices at the start in order to minimize the "money left on the table". That is why the minimum bid seems to drastically get lower towards the end of the bid. Also, and similar to real contractors, the autonomous RAB process simulates the bid delay for different contractors, which means that not all contractors react to a new minimum bid with the same speed. That is why each of the different 3 contractors seems to have a different time lag before lowering their bids. The final flat portion of the minimum bid at the end is the re-evaluation period.

The model can be further used to test various basic assumptions about RAB such as the fact that RAB proving lower prices than traditional bidding. Contractors can use the model to optimize their bidding strategy and increase their chances of winning more profitable bids. One can also study the effect of increasing the number of contractors on the final bid price. All these issues are points for further investigation and research.

Conclusions

Agent-based negotiation technology utilizes autonomous agents that act as a representative to the parties involved and interact to reach an agreement. Autonomous negotiation has recently gained interest among both researchers and professional due to its apparent potential to deeply transform the way business is conducted. In negotiating construction contracts, agent-based negotiation technology utilizes autonomous agents that act as a representative to the contractors and the owners and interact to reach an agreement. The main perceived benefit of using agent-based negotiation technology is the removal of the emotional component of the negotiations that so often result in less than Pareto-optimal agreements. This paper presents an approach to construction contract negotiations using a multi-agent system. We present a construction-specific model for negotiation between agents representing contractors in a Reverse Auction Bid (RAB). RAB is a fairly new electronic bidding model where contractors bid on a particular contract by iteratively lowering their bids. We specifically present a model that can deal with many-parties, single issue, multiple-encounter negotiations. A computerized system is developed to test the model. The system is used to run a number of numerical examples. An example is presented to demonstrate the application of the model in a real construction contract negotiation case. Furthermore, the developed system can be employed on line using the internet to allow for long distance negotiations through cyber space.

References

Anson, R. G., and Jelassi, M. T. (1990). ''A development framework for computer-supported conflict resolution.'' Eur. J. Oper. Res., 46, 181– 199.

Anumba, C. J., and Newnham, L. N. (2000). ''Computer-based collaborative building design: Conceptual model.'' Int. J. Constr. Inf. Technol., 8-1, 1–14.

Bacharach, S. B., and Lawler, E. J. (1981). Bargaining: Power, tactics and outcomes, Jossey-Bass, San Francisco.

Bell A. M. (2001), *Reinforcement learning rules in a repeated game*, Computational Economics **18**, 89-111.

Haltiwanger, J., Harrington, Jr. J.E., (1991). The impact of cyclical demand movements on collusive behavior. Rand Journal of Economics 22, 89–104.

Matsuo Tokuro, ITO Takayuki , Hendtlass Tim, Ali Moonis (2002), *"A designated bid reverse auction for agent-based electronic commerce, Developments in applied artificial intelligence"*, International conference on industrial and engineering applications of artificial intelligence and expert systems IEA/AIE 2002 N°15, Cairns , AUSTRALIE, 20021973, vol. 2358, pp. 460-469 (Cairns, 17-20 June 2002)

Ren Z.; Anumba C. J.; and Ugwu O. O. (2003), Multiagent System for Construction Claims Negotiation, Journal of Computing in Civil Engineering, Vol. 17, No. 3, July 1, 2003

Zeng, D., and Sycara, K. (1998). ''Bayesian learning in negotiation.'' Int. J. Human-Comput. Stud., 48, 125–141.

Zeuthen, F. (1975). ''Economic warfare.'' Bargaining: Formal theories of negotiation, O. R. Young, ed., University of Illinois Press, Urbana, Ill., 145–163.