Negotiating Agents in a Market-Oriented Grid

K-M Chao, R. Anane, J-H Chen, and R. Gatward
School of Mathematical and Information Sciences, Coventry University, UK
E-mail: {k.chao;r.anane;j.chen;r.a.gatward}@coventry.ac.uk

Abstract

The leasing of idle computing resources over the net is one way to motivate more participants to join the grid computation initiative. Since the participating parties are independent bodies, negotiation activities are required. In this research, we propose a new automated negotiation mechanism that allows each party to reach an agreement. The mechanism includes two methods: a co-evolutionary method and a game theory based method that is a trusted third party mediated game to facilitate the automation of negotiation between two participants. This mechanism allows them to reach a state that exhibits Pareto efficiency and Nash Equilibrium without knowing each other's utility function.

1. Introduction

Enabling idle computing resources to be re-allocated over the Internet to support applications that require intensive resource is one of main aims of the grid computation initiative. A number of government funded projects have demonstrated the successes of this initiative so far [1]. Recently, a number of commercial ventures also perceive the market advantages of this technology by proposing a market-oriented grid [1]. However, to prevail, the grid market does not only require the establishment of advanced grid infrastructures, but also an automated negotiation mechanism to allow participating parties (lenders and borrowers) to reach deals. A market-oriented grid and E-commerce share a number of objectives. Both advertise services and carry out business transactions through an electronic network (i.e. Internet). Whereas a market-oriented grid is concerned with one type of product – that of computational power, storage, and associated services, E-commerce deals with a wide range of products. Consequently, automated negotiation techniques developed for E-commerce can be applied to this emerging market. We characterise this type of negotiation as a multiple issue, frequent change of utility functions and incomplete information game.

2. Automated Negotiation

Negotiation can be viewed as a distributed search through a space of potential agreements. The structure of the negotiation object forms the dimensions and topology of the searching space [2]. Two components are important when designing an automated negotiation system: negotiation protocol and negotiation strategy. A number of researchers [2] adopted evolutionary approaches such as Genetic Algorithms (GAs) to find effective negotiation strategies through learning. However, this suffers from the difficulty of locating a globally optimised solution. A sub-optimal deal is often reached. The game theory negotiation approach also provides promising solutions to automated negotiation. The main weakness of this approach is that the complete payoff information, such as strategies and values in the payoff matrix, is not available during negotiation in most practical application domains.

The proposed system [3] consists of two processes that implemented two main algorithms: a Genetic Algorithm and a Non Fear Deviation (NFD) [4] equilibrium algorithm. The first process uses a co-evolutionary method to explore the search space in order to identify possible agreed pairs. This process involves offers and counter offers with multiple issues between two negotiating agents. The second process is to reason by using the payoff matrix generated by the co-evolutionary process in order to find an equilibrium. Negotiating agents can make decisions based on the equilibrium. If there is no agreement to be made, the above processes will be iterated. This iteration will not continue indefinitely because of time and resource constraints. The process stops when one of two conditions is met: an agreement is reached; or either or both agents reach their limit for time or resources.

The proposed negotiation protocol includes a number of rules that the agents must follow. Firstly, the deal cannot be made in the co-evolutionary process. Secondly, the issues they are negotiating must be the same throughout the negotiation process. Thirdly, if one agent makes an offer then the other agent must make a counter offer. Fourthly, compensation and guarantee communication actions allow agents to re-allocate the payoffs in the matrix in order to find a stabilised equilibrium. Finally, the mutually acceptable agreements can only be made after finding a new equilibrium and corresponding strategies.

Agent's negotiation strategies and issues form their initial chromosomes. After a number of evolutionary iterations with random mutations and crossovers, each

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agent selects the most effective strategies from its populations. The selected representative strategies from one agent play with each strategy from the other in order to form an actual payoff matrix.

The payoff matrix may have none, one or multiple Nash equilibria. If there is a unique Nash equilibrium, it may not be a Pareto-efficient point. In order to overcome this problem, we use the NFD equilibrium algorithm to find a new Nash equilibrium, which is also a Pareto-efficient point. If the agents agree on the target payoffs produced from the NFD equilibrium algorithm, it is still necessary to determine the actual strategies to achieve these payoffs. To discover these strategies the GA process used before is reapplied, but in this case the fitness function is based on the NFD equilibrium. The GA may not be able to find a strategy that produces the exact payoff in the NFD equilibrium, but one that is close.

In Market-Oriented Grid, issues such as prices, storage, specific, and process time etc can be encoded in the system. The hard and software constraints can be imposed on these issues. The system allows the negotiating agents without knowing each other utility function to make decisions based on the obtained utilities.

3. Discussion and conclusion

The Nash bargaining solution provides great insight into bargaining behaviours, but it is a one-stage bargaining game. The multiple issues and incomplete information bargaining games are not considered. The Alternating-Offer model [5] allows agents to take turns to make offers until the agreement is secured. It is similar to the nature of human negotiation behaviours. The model employs the sub-game perfect equilibrium concept and the Nash bargaining solution to support the theory. The model still assumes that the agent's utility functions are common knowledge. The perfect Bayesian equilibrium concept can be used to solve dynamic games with incomplete information. The difficulty of applying the perfect Bayesian equilibrium concept to negotiation is the identification of possibility. However, it cannot deal with multiple issues simultaneously. Gerding et al [6] used the game theory approach to resolve multiple issues. The method can only work on complete information games with very limited search space.

Oliver [7] first proposed a co-evolutionary approach to automated negotiation that relaxed a number of assumptions imposed by game theorists. The issues and thresholds are encoded in the chromosomes with random combinations throughout the co-evolutionary process to find the optimised agreed solution for negotiating agents. The result of this is that the agents may accept a worse deal than a previous one. Peyman [8] advanced this concept by introducing a set of family tactics in order to search optimised generic negotiation strategies. However, the negotiation objects may vary in different cases, so the utility functions may change for either or both agents. The best generic strategies do not guarantee good performance in all environments, because the dependent utility and fitness functions could be diverse. Furthermore, this work is built upon a unique existing Nash Equilibrium. However, the resulting payoff matrix may have none, one or multiple Nash equilibria.

The system [3] we propose provides an effective and practical approach for enabling negotiating agents to resolve conflicts. This work integrates the NFD equilibrium method built upon a game theory approach and co-evolutionary computing to form an effective and practical solution to automated negotiation. The main characteristic of the proposed method is that the negotiating agents can reach a stabilised point with multiple issues where one agent only knows about its own payoffs and strategies. This research overcomes a number of existing problems in game theory approaches and co-evolutionary approaches. Strategies are generated according to a known and fixed payoff matrix. However, finding the payoff matrix and generating effective strategies are not trivial tasks. We used GA to find effective strategies and then to produce the payoff matrix. Since the search space is unknown in the first place, the NFD equilibrium provides a reference point for the GA to search a refined equilibrium in the space.

4. References

[1] Buyya, R., Vazhkudai, S., Computer Power Market: Towards a Market-Oriented Grid, Proceedings of 1st IEEE/ACM International Symposium on Cluster Computing and the Gird, 2001, pp 574-581.

[2] Jennings. N. R., Parsons. S., Sierra. C., & Peyman F., 2000, Automated Negotiation, *Proc of 5th International Conference on the Practical Application of Intelligent Agents and Multi-Agent Systems* , Manchester, UK, pp. 23-30.

[3] Chen, J-H, Chao, K-M, et al. An Automated Negotiation Based on Co-Evolutionary and Game Theory, to appear *in Conference Proceedings of The 17th ACM of Applied Computing*

[4] Soo, V-W & Wu, S-H., 2000, Negotiation Without Knowing Other Agents Payoffs in the Trusted Third-Party Mediated-Game, *Second workshop on game theoretic and decision theoretic agents*.

[5] Binmore, K., Piccione, M., and Samuelson, L., Evolutionary stability in alternating-offers bargaining games. *J. of Economic Theory*, Vol. 80, No. 2, Jun 1998, pp. 257-291.

[6] Gerding, E.H., van Bragt, D.D.B., La Poitre J.A., Mutil-Issue Negotiation Processes by Evolutionary Simulation: Validation and Social Extension, http://www.cwi.nl/ bragt/

[7] Oliver, J. R., 1997, *On Automated Negotiation and Electronic Com*merce, PhD thesis, University of Pennsylvania.

[8] Peyman, F., 2000, *Automated Service Negotiation Between Autonomous Computational Agents*, PhD thesis, University of London.

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