

An Approach to Solve Winner Determination in Combinatorial Reverse Auctions Using Genetic Algorithms

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ABSTRACT

Nowadays, winner determination problem is one of the main challenges in the domain of real-time applications such as combinatorial reverse auctions. To determine the winner(s) in combinatorial reverse auctions, in our previous work, we have proposed a Genetic Algorithm (GA)-based method and have demonstrated its superiority in terms of processing time and procurement cost. One of the main drawbacks of traditional GA-based solutions is their inconsistency in different runs. In this paper, we perform a statistical-based experiment that reveals that our proposed method is not affected by the inconsistency issue. In addition, we show two other features of our GA-based method: (1) the quality of the solution improves over generations, and (2) the any-time behavior.

Categories and Subject Descriptors

I.2.8 [Artificial Intelligence] [Problem Solving, Control Methods, and Search]: Heuristic Methods

General Terms

Algorithms

Keywords

Winner Determination; Combinatorial Reverse Auctions; Genetic Algorithms

1. INTRODUCTION

In combinatorial reverse auctions, there are several sellers who compete according to the buyer's requirements. In this type of auctions, the buyer specifies his demand of multiple items and then the registered sellers bid on a combination of items. GAs [1] were successfully used to solve many combinatorial optimization problems [8] such as travelling salesman problem [6], quadratic assignment problem [3] and job scheduling problem [9]. To solve winner determination in combinatorial reverse auctions, still not much work has been done by using GAs. In our previous work [11], we have proposed a GA-based method to solve the winner determination problem specifically for combinatorial reverse auctions. Moreover, we have shown the superiority of our proposed method, in terms of processing time and procurement cost, over another method [8]. We assessed the processing time of our approach by varying the number of items as well as the number of sellers.

In many real-time applications, such as e-commerce and resource allocation problems, a quick response is expected. When problem instances are large and solutions are needed quickly, exact algorithms are not only inadequate but also infeasible as instances become larger [5]. In real-time applications, certain domains may require approximate solutions within an allowable processing time. Sometimes, it is unnecessary to expense a lot to better improve the quality of the solution. For these reasons, in this research we consider GAs to solve the problem of winner determination and our proposed algorithm [11] is able to produce good solutions from the very first generations. One of the main drawbacks of traditional GAs is that they produce inconsistent solutions in different runs which makes it difficult to perform a sensitivity analysis [4]. In this paper, we conduct a statistical-based analysis to demonstrate that our GA-based method does not suffer from the inconsistency issue. We also show that our method is able to improve the quality of the solutions over generations. The solution quality corresponds here to minimizing the bid price. In addition, we illustrate the any-time behavior of our GA-based method.

2. PROPOSED GA-BASED METHOD

To solve the problem of winner determination in combinatorial reverse auctions, we proposed a method using GAs that we named GACRA (Genetic Algorithms for Combinatorial Reverse Auctions) [11]. In that method, we defined two repairing methods, RemoveRedundancy and RemoveEmptiness, to repair infeasible chromosomes. In addition, we modified the two-point crossover to create a positive effect in order to increase diversity in the solution space. To avoid redundancy, the RemoveRedundancy method ensures exactly one selection of a particular item from all sellers in each chromosome. To avoid emptiness, the RemoveEmptiness method guarantees at least one selection of every item in each chromosome. Our modified two-point crossover allows bidders to get chances to be selected again since they can be deprived after removing redundancy and emptiness. This will prevent to converge prematurely. In fact, together with our modified two point crossover operator, these two methods make GACRA efficient as shown by the experimental test we report in the next section. In our procedure, we always preserve the current winner. So there is no chance to produce a worse solution than in the previous generation. Furthermore, GACRA is able to minimize the procurement costs from the very early generations as it does not allow redundancy. Hence, GACRA is appropriate when the allowable processing time is too short.

3. EXPERIMENTATION

In this paper, we assess GACRA by checking the consistency through a statistical-based analysis. We have performed in total 20 runs of GACRA in the same experimental environment as in our previous work [11], and have used the same parameters and operators, such as chromosome encoding technique, number of chromosomes, selection, crossover and mutation methods, crossover and mutation rates and termination condition. Each run consists of 500 generations. In Figure 1, we show the average bid price of 20 runs of GACRA represented by the solid line. The maximum and minimum values of bid price are indicated by '+' and '-' respectively. The error bars are also depicted with a confidence level of 95%.

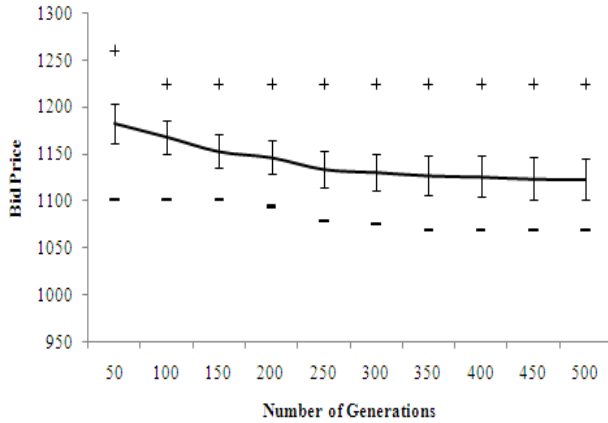


Figure 1. Bid price vs. number of generations with error bars.

To prove the consistency of GACRA, we perform 20 different runs. From the solutions given in Figure 1, it is easily notable that the variations of bid price in a particular generation over different runs are significantly smaller. Here, the solution corresponds to the bid price. Hence, GACRA is able to reduce the solution variations. This illustrates that it does not suffer from the inconsistency issue. Furthermore, GACRA gives consistently a better solution quality. It should also be noted that the solution quality increases steadily over the generations. After 50 generations, it produces an average bid price of 1182.75, whereas after 100 generations, it gives 1168.45 and it continues producing better solutions over the generations. It can also be seen that the variability of the solution quality over multiple runs improves over generations. From the very first till the 350th generation, the variability of the solutions fluctuates but after that, it is able to maintain the variability of the solutions almost the same. In addition, the minimum bid price remains constant after 350 generations. This suggests that the best solution found by GACRA might be the optimal solution to the problem. This experiment also illustrates the any-time behavior of the GACRA algorithm. Indeed, this latter is capable of returning the best solution within the allowable processing time.

4. CONCLUSION & FUTURE WORK

Motivated to overcome the drawback of inconsistency of traditional GA-based solutions, this research work assesses the consistency of GACRA through a statistical analysis and shows it as a consistent one.

There are several promising future directions of this research work. To improve further the consistency of the solutions and the efficiency of GACRA, the parameters of GAs, such as population size, crossover and mutation rate, may be tuned more effectively. Another future target of this work is to solve the problem of winner determination in combinatorial reverse auctions by using parallel GAs as they are capable of providing the solution more efficiently [7, 10] as well as messy GAs as they can solve more difficult problems than other GAs [2]. Moreover, to determine the winner(s), besides price, other bidding features, such as sellers' reputation and delivery time, can be considered.

REFERENCES

- [1] D. E. Goldberg and K. Deb, "A Comparative Analysis of Selection Schemes Used in Genetic Algorithms", Edited by G. J. E. Rawlins, pages 69–93, 1991.
- [2] D. E. Goldberg, B. Korb and K. Deb, "Messy Genetic Algorithms: Motivation, Analysis, and First Results", *Complex Systems* 3, pages 493–530, 1989.
- [3] D. M. Tate and A. E. Smith, "A Genetic Approach to the Quadratic Assignment Problem", *Computers and Operations Research*, vol. 22, no. 1, pages 73–83, 1995.
- [4] F. Li, "Genetic Algorithm Approach to More Consistent and Cost Effective Unit Commitment", *The 3rd World Congress on Intelligent Control and Automation*, vol. 1, pages 581–585, 2000.
- [5] H. H. Hoos, C. Boutilier, "Solving Combinatorial Auctions using Stochastic Local Search", *The 17th National Conference on Artificial Intelligence*, pages 22–29, 2000.
- [6] H. Watabe and T. Kawaoka, "Application of Multi-Step GA to the Travelling Salesman Problem", *The 4th International Conference on Knowledge-Based Intelligent Engineering Systems and Allied Technologies*, Brighton, UK, 2000.
- [7] M. Nowostawski and R. Poli, "Parallel Genetic Algorithm Taxonomy", *The 3rd International Conference on Knowledge-Based Intelligent Information Engineering Systems*, pages 88–92, 1999.
- [8] P. Patodi, A. K. Ray, M. Jenamani, "GA Based Winner Determination in Combinatorial Reverse Auction", *The 2nd International Conference on Emerging Applications of Information Technology (EAIT)*, pages 361–364, 2011.
- [9] P. Senthilkumar and P. Shahabudeen, "GA Based Heuristic for the Open Job Scheduling Problem", *International Journal of Advanced Manufacturing Technology*, vol. 30, pages 297–301, 2006.
- [10] R. Abbasian and M. Mouhoub, "An Efficient Hierarchical Parallel Genetic Algorithm for Graph Coloring Problem", *The 13th Annual Genetic and Evolutionary Computation Conference (GECCO)*, ACM, Dublin, Ireland, pages 521–528, 2011.
- [11] S. K. Shil, M. Mouhoub and S. Sadaoui, "Winner Determination in Combinatorial Reverse Auctions", *The 26th International Conference on Industrial, Engineering & Other Applications of Applied Intelligent Systems (IEA/AIE)*, in press, 2013.