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Buyer Formation with Bundle of Items in E-Marketplaces by Genetic Algorithm

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***Abstract*—There exist several commercial websites selling similar goods. To date, however, most existing buyer coalition schemes over the Internet have no focused on forming a buyer coalition with bundles of items. This paper presents the approach to form buyer coalition with bundles of items by using the genetic algorithm (GA), called GAGroupBuyer scheme. Buyers post their orders with some reservation prices to any items in the package list. The GAGroupBuyer scheme finds best formation of sub groups (coalitions) which can give the best of group's utility. The simulation results are compared with the GroupBuyPackage scheme [8]. The results indicate that the algorithm can improve the total discount of any coalitions.**

Index Terms— **Buyer formation, genetic programming, bundle of items.**

I. Introduction

A buyer coalition is a set of buyers who agree to cooperate and join together to bargain with sellers to achieve one purchasing goal. In real traditional market, most of buyers prefer to build the corresponding purchasing strategies to minimize the purchase cost, but it is impractical for a big group of buyers to build such purchasing strategies because of the high cost of accessing production information. However, in electronic marketplaces, it has become widely important because buyers can access through the Internet to get the product information easily. Moreover, buyers can advantageously negotiate with sellers to gain volume discount prices [14]. Conversely, it is one of the quickest ways for sellers to sell tons of products**.** Sellers can get better profits from selling in large number of products. As the result, more commercial WWW sites are available on the Internet. There exist several opportunities to form a buyer coalition on the Internet if buyers gain better benefits from the coalition. However, most researchers do not consider forming sub groups of buyer with bundles of items[1] which can be often occurring in the real world. For instance, buyers cannot purchase the bundles of items by their own because the packages of products sold by sellers are composed of several items or multiple types of items.

In this paper, the GAGroupBuyer scheme based on GA is applied to the set of buyers who want to purchase some particular items within the packages, but each buyer cannot buy the whole package by itself. The concentration of this paper is to find the best formation of the group buyers which can give the better of group's utility. GA is a heuristic search scheme based on a model of Darwininian evolution [15]. So, there is no guarantee for convergence of GA, but the experiments have shown in most cases that the approach is acceptable. The paper is divided into five sections, including this introduction section. Section 2 provides related works. Section 3 describes the problem of buyer coalition with bundles of items and GAGroupBuyer algorithm in detail. Section 4 presents the GAGroupBuyer scheme simulation setup and experimental results of scheme. The conclusions and future works are in Section 5.

II. Related Works

There are several buyer coalition schemes with the aim of having best group utilities. The most buyer coalition schemes form a buyer coalition in the electronic market to gain the discount for buying a large number of goods [1,2,4,13]. The GroupBuyAuction scheme [14] forms a buyer coalition based on item categories. Then, the Combinatorial Coalition Formation scheme [7] considers an e-market where each buyer places a bid on a combination of items with reservation prices, and sellers offer price discounts for each item based on volume. Hyodo, Matsuo, and Ito [5] optimally allocate buyers to several group buying sites that are selling similar (or the same) goods by a genetic algorithm. Then, buyers with multi-attribute preferences (utility) are integrated into a coalition in Matsuo, Ito, and Shintani's work [9]. This system supports buyers' decision making by using the Analytic Hierarchy Process. In He and Ioerger's work [4], each buyer needs to buy different goods as a bundle and sellers offer discount policies based on the total cost of all goods sold in one transaction. This paper found the optimal purchasing strategies that maximized the discount to buyers. The other buyer coalition scheme is a coalition of buyers, given the incentive of obtaining a volume discount according to the size of the coalition [14]. Also, the research of Tsvetovat, M., Sycara, K.P., Chen, Y. and Ying, J. [13] uses incentives to create buying group**.** However, there is only one scheme of Laor, B., Leung, H. F., Boonjing and V.,Dickson, K. W. [8] that forms a buyer coalition with bundles of items.

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[1] bundles of items refers to the practice of selling two or more goods together in a package at a price which is below the sum of the independent prices [3].

III. Buyer Coalitions with Bundles of Items

The motivating example and the formal definition of forming buyer coalition with bundles of items will be described as following to illustrate the problem.

A. Example

There exist several commercial websites, such as http://www.amazon.com and http://www.staples.com/. Ordinarily, these websites provide some attractive products with the special prices. Suppose that there are 4 kinds of products selling in the e-marketplace, which are toilet paper, paper tower, lotion, and detergent. The sellers make a price list for their products; both single item and bundles of items, as shown in Table 1. For instance, package number 3 of seller 1 (s_1) composes of two packs of toilet paper and four packs of paper tower. This package is sold at the special price of \$59.76. However, a single-pack of toilet paper and a four-pack of paper tower are sold separately at the price of \$12.00 and \$40.21 by seller 0, as seen in package number 1 and 3 of seller 0, respectively. The symbol '-' appearing in the Table 1 means that the seller does not put the product item in that package number. There are some buyers who want to purchase some products listed in the Table 1. Due to the buyer demands and economic problems, some buyers do not want to buy the whole bundle of items by their own. They come to participate in the group buyer with the aim of obtaining better prices on the purchasing. Suppose there are four buyers joining into the particular group. Each buyer denoted as b_m where m > 0 places some orders to the specific items at the reservation as shown in Table 2. For instance, buyer b_0 wants to buy 2 packs of toilet paper at the reservation price of \$9.10 of each and a pack of lotion at the reservation price of \$6.55. These reservations of each mean the prices for particular items that buyers are willing to pay. The symbol '-' in Table 2 means that buyers have no requests to buy the specific product.

TABLE I. The price List Example

Seller	Package number	Product Types				Price ($)
		toilet paper	***paper tower***	***lotion***	***detergent***	
s_0	0	pack of 1	-	-	-	12.00
	1	pack of 4	-	-	-	36.08
	2	-	pack of 4	-	-	40.21
	3	-	-	pack of 1	-	7.89
	4			pack of 3	pack of 2	18.93
s_1	0	-	-	-	pack of 9	47.21
	1	-	-	-	Pack of 1	8.00
	2	-	pack of 4	pack of 3	-	40.64
	3	pack of 2	pack of 4	-	-	59.76
	4	-	pack of 2	pack of 3	pack of 3	52.00

TABLE II. The Sample of Buyers' Order

Buyers	Buyer's Order (Number of item × (price $))			
	toilet paper	***paper tower***	***lotion***	***detergent***
b_0	2 × (9.1)	-	1 × (6.55)	-
b_1	-	-	-	2 × (5.95)
b_2	-	-	3 × (6.0)	1 × (6.0)
b_3	1 × (9.1)	4 × (10.0)	-	-

B. Assumptions

1) The buyer coalition is formed concerning only the price attribute, and each buyer in the group cannot buy the whole bundle of items by buyer itself.

2) Buyers have several choices of items, and they have seen the price list of all packages provided by sellers before they can place their orders.

3) Sellers can supply unlimited items of any products.

4) Packages in this experiment are mixed bundling, but some of the single item can be sold separately.

5) The discount policy of sellers based on the number of items bundled in the package. If the package is pure bundling, the average price of each item will be cheaper than the price of a single-item package.

C. Problem Formalization and Algorithm Designing

There is a set of sellers $S = \{s_0, s_1, s_2, \ldots, s_i\}$ offering to sell partial or all goods of $G = \{g_0, g_1, g_2, \ldots, g_j\}$. The seller i has made special offers and production promotions within a set of packages, denoted as $Package^i = \{package^i_0, package^i_1, package^i_2, \ldots, package^i_k\}$ Each package is associated with the set of prices, denoted $Price = \{price^i_0, price^i_1, price^i_2, \ldots, price^i_k\}$, where the $price^i_k$ is an item list denoted by a vector $\{g^{ik}_0, g^{ik}_1\ g^{ik}_2, \ldots, g^{ik}_j\}$. If any goods g_j is not available in the $package^j_k$ of seller s_i, $g^{ik}_i = 0$. Let $B = \{b_0, b_1, b_2, \ldots, b_n\}$ denote the set of n buyers participated in the group buyer. Each buyer b_m needs to buy some items offered by sellers, denoted as $Q_m = \{q^m_0, q^m_1, q^m_2, \ldots, q^m_j\}$, where q^m_j refers to the quantity of items g_j of buyer m. If $q^m_j = 0$, it means that buyer b_m does no request to buy goods g_j. Also, any buyer b_m can put the reservation price for each particular item associated with Q_m, denoted as $Rs_m = \{rs^m_0, rs^m_1, rs^m_2, \ldots, rs^m_j\}$. The object of the problem is to find best utility of the coalition; the following terms and algorithm processes are needed to define.

Coalition: A coalition is a set of buyers who join together with one purchasing purpose.

Sub-coalitions: A coalition can be divided into small groups of buyers called sub-coalitions, denoted as C_n which $C_n \subseteq B$ and $C_0 \cap C_1 \cap \ldots Cn = \emptyset$. In the previous statements of this section assume that each buyer in the group cannot buy the whole bundle of items by buyer himself meaning that all sub-coalitions with $|C_n| = 1$ will not be concerned in the buying group. However, if any buyers have placed some bad orders (or unacceptable reservation prices) which can not be bough by any sub-coalitions, these buyers will be out of the coalition. So, from the motivating example, $B = \{b_0, b_1, b_2, b_3\}$, there exits only thirteen possible ways to form the coalition as shown below:

One sub-coalition: $\{b_0,b_1\}$, $\{b_0,b_2\}$, $\{b_0,b_3\}$, $\{b_1,b_2\}$, $\{b_1,b_3\}$, $\{b_2,b_3\}$, $\{b_0,b_1,b_2\}$, $\{b_0,b_1,b_3\}$, $\{b_0,b_2,b_3\}$, $\{b_0,b_1,b_2,b_3\}$

Two sub-coalitions: $\{\{b_0,b_1\},\{b_2,b_3\}\}$, $\{\{b_0,b_2\},\{b_1,b_3\}\}$, and $\{\{b_0,b_3\}, \{b_1,b_2\}\}$.

BuyerPackageSeries is the chromosome of sub-coalition together with a sequence of random packages with the specific size of L. Suppose the given sub-coalitions set of B is $C_n = \{b_0,b_3\}$, then GAGroupBuyer scheme randomly built the BuyerPackageSeries for C_n in the structure of

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BuyerPackageSeries = $C_n < Package_i^{j^{th}} >^L$, where i refers to the seller s_i and j^{th} is the number of the package provided by seller s_i. For instance, in the case of L = 3, if there is a given set S = $\{s_0, s_1\}$ and each seller has five differences of packages (k = 5), then the possible BuyerPackageSeries for sub-coalition C_n = $\{b_0,b_3\}$ would have been BuyerPackageSeries = $\{b_0,b_3\}$<$Package^0_0 Package^1_1$ $Package^1_1$>. It means that this sub-coalition C_n needs to purchase one of $Package_0$ from seller s_0 and two of $Package_1$ from seller s_1. If there are m buyers participating in the group, and i sellers with k different packages, then the possible numbers of BuyerPackagesries in the search space are $(2^m\text{-}m\text{-}1)(i)(k^L)$, where L is the fixed size of strings in the BuyerPackageSeries.

Total Utility of Coalitions: The utility of a coalition is a discount obtained by purchasing goods. The GAGroupBuyer scheme randomly searches several generations (Gen) to find the best BuyerPackageSeries for the selected sub-coalition. The utility of the sub-coalition C_n, denoted U_n, is the defined as following, $\sum_{b_m \in C_n} \sum_{j=1}^{k} rs_j^m * q_j^m - \sum_{i=0}^{L}$ (Price of Package), where k is the number of product types selling by sellers, $\sum_{b_m \in C_n} \sum_{j=1}^{k} rs_j^m * q_j^m$ is the sum of all buyers' reservations of the sub-coalition, and $\sum_{i=0}^{L}$ (Price of Package) is the budget of this sub-coalition C_n needed to buy those packages in BuyerPackageSeries.

Fig. 3 is a flowchart of GAGroupBuyer algorithm. The algorithm begins with generation 0 with the completely random population of BuyerPackageSeries with the size M. There exist two operations to perform during one generation, crossover, and mutation. During the run, a given individual might be mutated and crossed with in single generation. GAGroupBuyer scheme searches the space of possible BuyerPackageSeries in an attempt to find good BuyerPackageSeries based on fitness value. In this algorithm, the fitness function is inherent in the population of BuyerPackageSeries it encounters.

Fitness value: The fitness value to each member in the population is the total utility of a coalition. The underlining idea is to generate successive sets of generations, making each new generation from the best population of the precedent. The two major steps in the GAGroupBuyer scheme to solve the problem are described below.

Step 1 Setting the parameters and variables

For controlling the GAGroupBuyer scheme, the primary parameters for controlling the algorithm are the population size (M) and the maximum number of generations to be run (Gen). Secondary parameters, the crossover probability (p_c), the percentage of current population needed to participate in the crosser operation, and the mutation probability (p_m), the percentage of current population needed to participate in the mutation operation, are required to create new population.

Step 2 Algorithm process

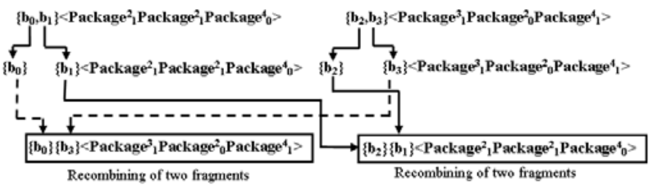
Once the setting up of the GAGroupBuyer algorithm has been competed, the algorithm can be run. There are three substeps in executing the algorithm operating on each sub-coalition of the group can be summarized as follows:

1) Randomly create BuyerPackageSeries for an initial population. The fundamental rule must be applied; the difference size of sub-coalition of the group buyer where $|C_n| > 1$.
2) Calculate the utility of each individual in the population, and examine all buyers of the sub-coalition in BuyerPackageSeries to make sure that their requests are certainly in the process.
3) Create a new population of BuyerPackageSeries for the next generation based on fitness value by randomly applying two following operators.

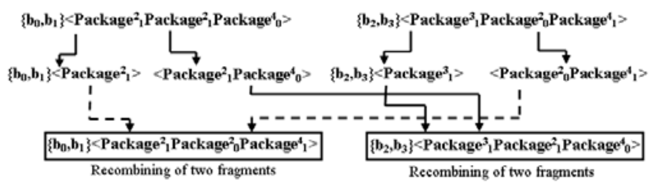
- **Crossover operation**: Create two new offspring from two best existing parents of current generation in the population by recombine randomly chosen BuyerPackageSeries at a crossover point. Suppose the best two BuyerPackageSeries participating in crossover with L = 3 are $\{b_0,b_1\}$<$Package^2_1$ $Package^2_1 Package^4_0$> and $\{b_2,b_3\}$<$Package^3_1$ $Package^2_0 Package^4_1$>. Each parent will be split at the crossover point into two substrings, a crossover fragment and the remainder. There are two ways of operating the crossover, buyer crossover and package crossover. The possible resulting of recombining two substrings is shown in Fig. 1.

- **Mutation operation**: Create a new offspring from best existing members in the population. The mutation process begins by randomly selecting BuyerPackageSeries of current sub-coalition set, and then randomly choosing number as the mutation point for each BuyerPackageSeries. The chromosome at this mutation point of selected BuyerPackageSeries is randomly changed. Suppose the random selecting BuyerPackageSeries is $\{b_0,b_1\}$<$Package^2_1 Package^2_1$ $Package^4_0$>. The two possible resulting of mutation operation is shown in Fig. 2.

4) The algorithm keeps processing in step 2 and 3 finding new population for each generation until it gets maximum number of generation to be run. The best BuyerPackageSeries of each sub-coalition, which are possible to yield the highest profit to the group buyer



a) buyer crossover



a) package crossover

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Figure I. Resulting of the crossover operation

based on the fitness value, might be found. If the set of four buyers is divided into two sub-coalitions, $\{b_0,b_1\}$ and $\{b_2,b_3\}$, and $\{b_0,b_1\}$<$Package^2{}_1Package^2{}_1$ $Package^3{}_0$> together with $\{b_2,b_3\}$<$Package^2{}_1Package^1{}_1$ $Package^1{}_1$> give the highest total utility, then the total utility of the coalition is $U = U_{\{b_0,b_1\}} + U_{\{b_2,b_3\}}$.

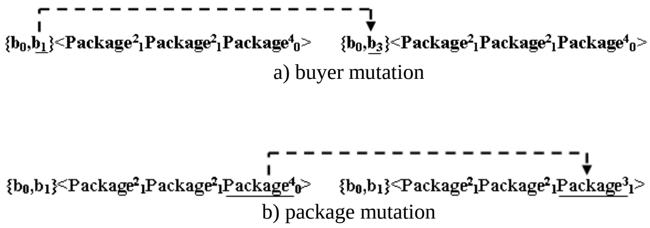

Figure II. Resulting of the mutation operation

IV. Experimental Results and Discussion

In this section, we have used the simulation to show the performance of the proposed GAGroupBuyer scheme. The simulation has implemented more than 4000 lines of C++ program. They are run on a Pentium(R) D CPU 2.80 GHz, 2 GB of RAM, IBM PC. The algorithm has been tried several of runs with different values of the population size (M), mutation probability (p_m), and crossover probability (p_c), to find which values would steer the search towards the best solution. From the experiments, the fixed parameters are the crossover probability p_c = 0.95, mutation probability p_m = 0.05, and the population M = 1000. Table 3 summarizes the simulation parameters. In order to get best experimental results, the three set of data with the different of criteria used in the experiment as seen in Table 4. Each test of them operates several runs. Finally, the average result of the experiment is shown in Table 5. The experimental results of three tests obviously show that the GAGroupBuyer scheme can find the better total utility than the scheme in [8] when the number of generations is high enough. As we can see from test number 2, the GAGroupBuyer scheme can form the group buyer by separating buyers into five sub-coalitions, and it has found that 2 buyers are not qualify based on their reservations. The coalition can be formed by having 5 sub-coalitions, and only 18 of buyers can purchase the goods. The average of total utility of the test no. 2 is 130.64.

The Fig. 4 shows the simulation results of three tests. Because the GroupBuyPackage scheme is a definite method, thus it needs to operate only one time. The horizontal axis of this graph is the number of generations. The vertical axis of this graph is the utility of the coalition. Brief justifications for the values of these figures are M = 1000, pc = 0.95, and pm = 0.05. In the experiment with different scales of data, the algorithm gives better outcomes when the number of generations (Gen) has increased. For each test of the experiments, when the generation of GAGroupBuyer scheme is low, the GroupBuyPackage performs better. However, when the number of generations is high enough, the curves of the GAGroupBuyer graph increase rapidly. It is because the quality of the formed buyer coalition improves after each generation.

TABLE III. Summarize the parameters simulation for GAGroupBuyer algorithm

Constant	Detail	Range
NumOfBuyer	No. of buyers	10-20
NumOfSeller	No. of Sellers	2
NumOfPackagePerSeller	No. of packages for each seller	5
NumOfItemPerPackage	No. of items/ package	5
NumOfPackage	No. of package for each seller	5, 10
Gen	No. of generation to be run	800
NumOfPopulation	Population size	1000
pc	Crossover probability (p_c)	0.95
pm	Mutation probability (p_m)	0.05
L	Fixed size of packages in the BuyerPackageSeries	12

TABLE IV. Data settings for simulation

No. of Test	NumOfBuyer	NumOfSeller	NumOfPackage PerSeller	NumOfItem/ Package
1	10	1	10	5
2	20	1	10	5
3	20	2	5	5

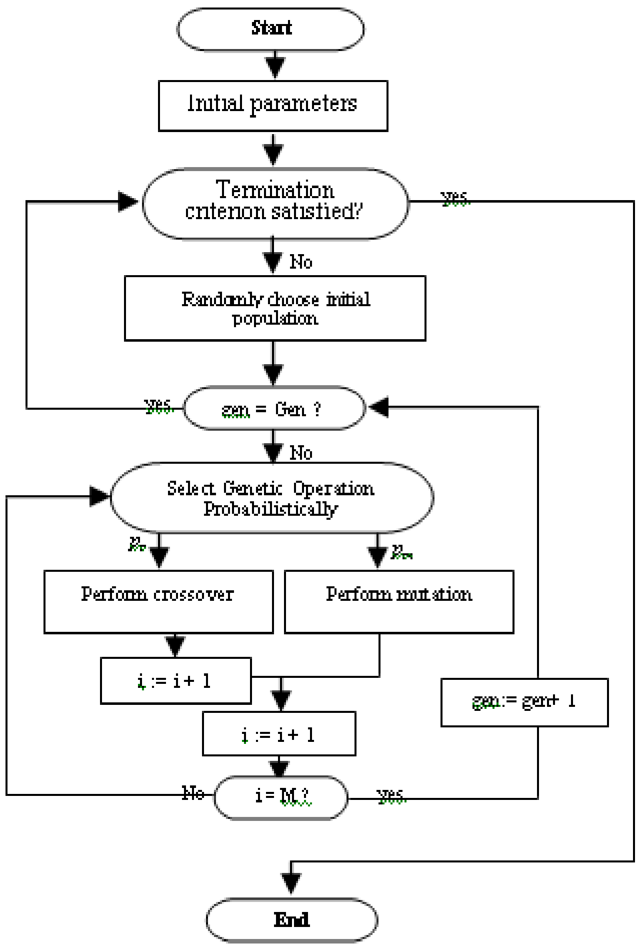

Figure III. Flowchart of implementation the GAGroupBuyers scheme

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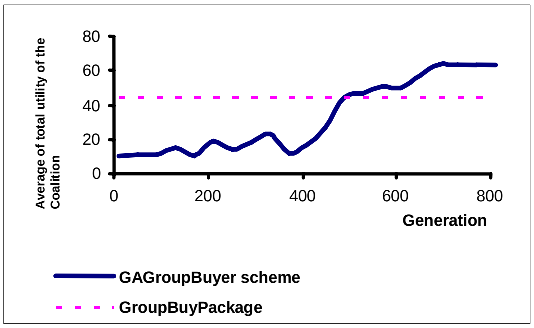
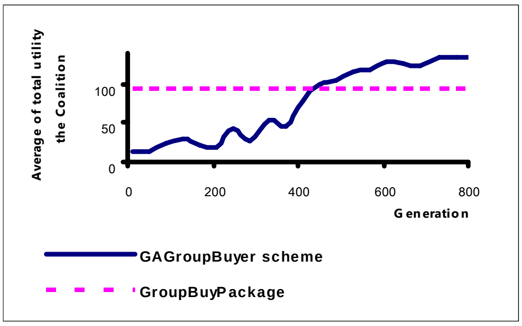
TABLE V. EXPERIMENTAL RESULTS FOR THREE TESTS

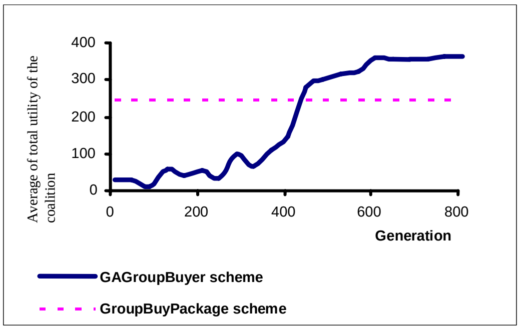
No.of test	GAGroupBuyer scheme			Scheme in [8]	
	Total sub-coalitions	*Total buyers who can purchase the items*	*Avg. of total utility*	*Total buyers who can purchase the items*	*Avg. of total utility*
1	3	10	63.50	10	44.50
2	5	18	130.64	20	95.37
3	2	20	364.83	20	247.45



(a) first test.



(b) second test.



(c) third test.

Figure IV. Comparison result to GroupBuyPackage scheme[8]

V. CONCLUSION AND FURTHER WORK

This paper presents the algorithm called GAGroupBuyer scheme for forming buyer coalition with bundle of items. A number of experiments using in the tests are in the real world. The GAGroupBuyer scheme is appropriate for the events in which the buyers cannot buy the bundles of items by their own. All members in the group may get more discounts (or utilities) when the discounts from buying the items individually is lower than the discounts from purchasing bundles of items. From experimental result, Table 5 shows conclusively that the average of total utility of any coalitions formed by GAGroupBuyer scheme is better when the number of generations has increased. However, some restrictive assumptions do apply as follow 1) the buyer coalition is formed concerning only the price attribute, and any buyers of the coalition cannot buy the bundles of items by themselves 2) buyers have made several choices of items, and they have seen the price list of all packages provided by sellers before they can place their orders 3) all buyers do not know each other in the coalition 4) sellers can supply unlimited items of any products 5) packages in this experiment are mixed bundling, but some of the single item can be sold separately 6) the discount policy of sellers based on the number of items bundled in the package. If the package is pure bundling, the average price of each item will be cheaper than the price of a single-item package.

REFERENCES

[1] Chang, Y., Li, C., and Smith, J. R., Searching dynamically bundled goods with pairwise relations, in proceedings of ACM Electronic commerce, 135-143, 2003.
[2] Chen, D., Jeng, B., Lee, W., and Chuang, C. 2008. An agent-based model for consumer-to-business electronic commerce. Expert Systems with Applications, 34(1): 469-481.
[3] Gurler, U., Oztop, S. and Sen A., 2006, Optimal Bundle Formation and Pricing of two products with limited stock, J. International Journal of Production Economics (2008).
[4] He, L. and Ioerger T., 2005, Combining Bundle Search with Buyer Coalition Formation in Electronic Markets: A Distributed Approach through Explicit Negotiation, Electronic Commerce Research and Applications, Vol. 4, No. 4, pp. 329-344.
[5] Hyodo, M., Matsuo, T.,Ito, T.: An Optimal Coalition Formation among Buyer Agents based on Genetic Algorithm. In" Chung, P.W.H", Hinde, C.J', Ali, M' (eds.) IEA/AIE 2003 LNCS(LNAI), vol. 2718, pp. 151-157. Springer, Heidelberg (2003).
[6] Koza, J.: Genetic Programming on the Programming of Computers by Means of Natural Selection. The MIT press Cambridge, Massachusetts, London (1992).
[7] Li, C', Sycara, K. Algorithm for Combinatorial Coalition Formation and Payoff Diversion in an Electronic Marketplace. In: Proceedings of the First International Joint Conference on Autonomous Agents and Multiagent Systems, pp. 120-127 (2007).
[8] Laor, B., Leung, H. F., Boonjing, V., Dickson, K. W., Forming Buyer Coalitions with Bundles of Items. In: Nguyen NT, Hakansson A, Hartung R., Howlett R., Jain LC (eds.) KES-AMSTA 2009. LNAI 5559-0717 PP 121-138. Springer, Heidelberg (2009).
[9] Matsuo, T., Ito, T., Shintani, T.: A Buyers Integratiion Support System in Group Buying. In: Proceedings of the IEEE international Conference on E-Commerce Technology, pp. 111-118 (2004).
[10] N. Tsvetovat, K. P. Sycara, Y. Chen, and J. Ying, Customer coalitions in electronic markets, In Proc. of AMEC-2000, pages 121–138, 2002.
[11] Sandholm, T., Larson, K., Andersson, M., Shehory, O., and Tohm, F. 1999. Coalition Structure Generation with Worst Case Guarantees. Artificial Intelligence, 111(1-2), 209-238.
[12] Thomas Back, Self-adaptation in genetic algorithms, Proceedings of the First European Conference on Artificial Life, pp. 263-271.
[13] Tsvetovat, M., Sycara, K. P., Chen, Y. and Ying, J., Customer Coalitions in Electronic Markets, Lecture Notes in Computer Science, Vol. 2003, pp. 121-138. Springer, Heidelberg (2001).
[14] Yamamoto, J. and Sycara, K., 2001, "A Stable and Efficient Buyer Coalition Formation Scheme for E-Marketplaces", Proceedings of the 5TH International Conference on Autonomous Agents, Monttreal, Quebec, Canada, pp. 576-583.
[15] Yang, T. and L. Hsiangchu, 2006, "Comparison of product bundling strategies different online shopping behaviors", Electronic Commerce Research and Applications, Vol. 5, Issue 4, pp. 295-304.

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