Buyer's Coalition for Optimal Search

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1. INTRODUCTION

In the context of the electronic marketplace, the most common coalition formation application is a coalition of buyers, given the incentive of obtaining a volume discount according to the size of the coalition [3]. In this paper we consider an additional benefit of a buyers' coalition, the benefit of improving the search for market opportunities through a coalition, given search costs. The buyer agents are considered to be associated with search costs when there are no available central mechanisms that can supply full immediate information on the entire market opportunities. These search costs reflect the resources that need to be invested in search activities, such as locating seller agents, interacting with them and analyzing and comparing their offers.

The existence of the search cost, creates a strong incentive for buyer agents to jointly search for potential opportunities through forming a coalition. We assume that the agents forming the coalition delegate their search to a representative agent. Obviously the search as a coalition produces some overhead, however the underlying assumption is that the representative agent's search cost associated with locating and interacting with a seller agent is smaller than the sum of such costs when each agent searches individually [2]. We take the coalition's structure as an input and analyze its optimal strategy (the one which maximizes its overall utility). Given the representative agent's goal of maximizing the overall coalition utility, its decision is not influenced by the payoff division protocol, nor coalition stability considerations, but rather influences these two factors.

This research considers two variants of the model, differing in the similarity level between the buyer agents' utility function. The first variant considers homogeneous agents with a similar utility function, and is applicable to simple products (like CDs) where the utility mainly relates to the price. In the second variant, we consider heterogeneous agents where each agent has its own unique utility function, applicable to more complex products. For each variant we consider the search problem in two different markets: The B2C (Business-to-Consumer) market, where sellers can supply almost any volume under demand, and the C2C (Consumer-to-Consumer) market, where sellers offer single items for sale. We show that every combination of agent similarity and market type, suggests a different optimal strategy of the representative agent.

Once a coalition is formed, the representative agent's search problem cannot be seen as equivalent to the single buyer agents' problem. Rather than searching for a single opportunity, the representative agent seeks an *opportunities set* which maximizes the sum of its coalition members' utilities. Here, the set of known opportunities actually influences the tradeoff between continuing the search (possibly resulting in better opportunities) and terminating it (obtaining an immediate gain for the coalition). To the best of our knowledge this type of problem has not been investigated to date.

2. STRATEGY FOR B2C MARKETS

Operating in a B2C market, the representative agent can assign any new opportunity encountered to any number of buyer agents in the coalition. A possible scenario in this market is where buyer agents are homogeneous (i.e. share a similar utility function). This is mainly common in B2C markets for simple products (like CDs or books), where the buyer agent's utility is typically associated with a limited set of terms (e.g. product price and shipment). Though the homogeneous scenario is a specific case of the heterogeneous scenario, we suggest that it possesses several unique characteristics in terms of strategy structure. Since all agents share the same utility function, they will all benefit most from the same singular opportunity, given any set of opportunities found. Thus, in the presence of the search cost the representative agent uses a reservation value based strategy. According to this strategy, the representative agent sets a reservation value and terminates the search when reaching an opportunity that yields a utility greater than or equal to the reservation value.

Since the coalition structure, the opportunities distribution and the search cost remain constant over time, the representative agent's search strategy in this case is stationary (i.e. it does not change from one search stage to another).

PROPOSITION 1. *If the coalition search cost increases at a decreasing rate then the average expected utility for any single participant buyer agent in the coalition, increases as a function of the number of buyer agents in the coalition,* N.

Proposition (1) suggests that in the absence of any coalition creation costs, the coalition should aspire to increase its size as much as possible. Nevertheless, recognizing the existence of costs associated with the coalition formation and maintenance process [2], the coalition size can be limited. These costs are quite similar in their structure to the search cost, since the set of actions the representative agent needs to perform in order to increase its coalition (locating potential buyer agents, interacting with them, etc.) resembles the process of finding potential seller agents in the marketplace. Notice that the increase in the average utility per participat-

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ing agent is bounded, thus in many scenarios the optimal coalition size can be extracted by finding a size by which the average cost associated with locating an additional buyer agent for extending the coalition is greater than the resulted increase in each coalition member's average utility. In the latter scenario one may also consider the possible discount in opportunity price as a function of the coalition size.

When considering agents with heterogeneous utility functions, the major benefit of a search through a coalition is the potential of exploiting opportunities which are discarded in the equivalent single search process (where each agent searches by itself). In comparison to the scenario of a cooperative search by homogeneous agents, the probability of having a new opportunity which improves the coalition utility is greater in the heterogeneous case. Nevertheless, the improvement itself is generally smaller as it is not necessarily associated with all coalition members as in the homogeneous case. Furthermore, in this case the determination of whether a search through a coalition is beneficial, in terms of the overall members' utility, is not as trivial as in the homogeneous case. Here, the difference between the expected utilities obtained using the two methods (cooperative search and aggregated separate autonomous searches) depends on the opportunities' distribution and the similarity level between the coalition members' utility functions (in addition to the search cost parameter). An exception to the above, is a scenario where the coalition has no overhead, as suggested in the following proposition.

PROPOSITION 2. *When the coalition does not produce any overhead search costs, the search through a coalition of heterogeneous agents will always improve the overall utility (the sum of the members' utilities).*

Consider a representative agent representing N agents with different utility functions operating in a B2C marketplace. Throughout its search, the representative agent maintains for each agent the opportunity with the maximum utility out of all opportunities known at the current point. Notice that the same opportunity might be reused for more than one agent in the set. Unlike the agent representing homogenous buyer agents, here the representative agent cannot use a utility based simple reservation value termination rule, but rather needs to consider the structure of its set of known opportunities as an input for its decision. The representative agent will terminate its search at any given stage if the immediate utility obtained by exploiting the best known opportunity for each agent is greater than the expected utility from resuming the search.

Our analysis suggests an efficient algorithm which facilitates the calculation of a representative agent's optimal strategy. The algorithm starts from a set of known opportunities, and returns the appropriate set of decisions to be taken given any future sets of opportunities.

3. STRATEGY FOR C2C MARKETS

The advantage of better utilizing each scanned opportunity when searching through a coalition holds also in C2C markets. Nevertheless, here the representative agent needs to supply each member of the coalition with a different opportunity (as sellers offer single items), thus an opportunity which potentially improves the utility of several buyer agents in the coalition can be applied only to one of them. This means that the expected performance of the coalition in C2C markets will be lower than in B2C markets.

The analysis methodology for this case is quite similar to the one used in the previous section. However the restriction of using an opportunity for the benefit of only one coalition member, requires a permutation analysis for evaluating the improvement obtained by any new opportunity encountered. Similar to the B2C case, we can suggest an efficient algorithm which facilitates the calculation of a representative agent's optimal strategy in C2C markets.

Nevertheless, for the special case of homogeneous agents operating in a C2C market, we prove that a search through a coalition is never beneficial. In this case the cooperative search will always underperform in comparison to the sum of single utilities obtained by each member searching autonomously by itself. Intuitively this can be explained by recognizing that it is irrelevant to consider reuse of a formerly rejected opportunity by one agent for the benefit of another in the coalition.

4. DISCUSSION AND CONCLUSIONS

In many markets associated with a search cost, autonomous agents have a strong incentive to search as a coalition. Such search method results in better utilization of the opportunities being scanned and reduces the average search cost per opportunity, thus increasing the overall utility in comparison to autonomous separate search activities.

Given today's electronic markets, the most applicable combination out of the four analyzed seems to reside in B2C markets. Here, both homogeneous agents' coalitions and heterogeneous agents' coalitions can be considered, according to the complexity of the product. Additionally, in these markets the concept of volume discount is applicable, increasing the incentive of the agents to cooperate (in this case the agents will benefit both from reducing the search cost and the discount price). In C2C markets products highly vary in brand, quality and age, thus it is more difficult to formulate the buyer agents' utility function. Nevertheless, we do believe that agents in future C2C markets will also benefit from such models.

Other than extracting the optimal search strategy for the coalition representative agent, the coalition formation process involves many issues that were not included in the scope of this research. The two most important issues are coalition stability, given the MAS settings and the division of payoffs (in terms of side payments) between coalition members. The optimal representative agent's strategy and its associated expected utility are important inputs for the analysis of these two issues. The rich literature in the area of game theory and MAS research [4, 1], enable us to adopt many results and ideas to resolve these issues for the model presented herein. Currently, we are evaluating the stability of the coalition when payoffs are divided according to a member's contribution to the overall coalition utility.

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5. REFERENCES

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