Budget Feasible Mechanisms in Auction Markets: Truthfulness, Diffusion and Fairness

Doctoral Consortium

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ABSTRACT

Budget feasible mechanism design, as a sub-field of auction domain, has been well studied in many previous works [5]. In budget-feasible mechanism design problem, there is a buyer with a budget and multiple strategic sellers owning items with private costs. The goal of the buyer is to procure as many items as possible from sellers. Thus, the designed mechanisms should ensure desirable properties, e.g., truthfulness of sellers, individual rationality, budget feasibility that the total payment cannot exceed buyer's budget. Although many works focused on budget-feasible mechanism design, there are still three further directions: 1) Budget feasible mechanisms in social networks where all participants are connected by their neighbors via social network and the buyer wants her neighbors to further diffuse auction information to other potential sellers to improve her utility; 2) Budget feasible mechanisms with fair representation where the agents may belong to different groups and the buyer wants to fairly select agents from different groups; 3) Budget feasible mechanisms in two-sided markets where there are multiple strategic buyers with diverse budgets and multiple strategic sellers with private costs.

KEYWORDS

Auction Theory, Budget Feasible Mechanism, Mechanism Design, Fairness

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1 BUDGET FEASIBLE MECHANISMS

Auction theory, as a common paradigm for multi-agent resource allocation, has enabled a wide range of applications, *e.g.*, wireless spectrum auctions and mobile crowdsourcing markets. Much effort over past decades focused on designing mechanisms to regulate trading behaviors in markets, *e.g.*, seller-centric auction where a seller sells items to buyers, or buyer-centric/reverse auction where a buyer procures items from sellers. Among the extraordinary progresses, the budget-feasible mechanism design in reverse auctions was initially studied in [5], where payments used to regulate behaviors should satisfy the budget constraint.

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1.1 Budget Feasible Mechanism Over Social Networks

Many existing works assume that sellers are reachable to the buyer and ready to join the auction campaign. However, in reality, many potential sellers will be unaware of the auction information if none of their acquaintances propagates information to them.

In order to propagate auction information to more potential sellers, the buyer can adopt the traditional advertising mechanisms. However, the high agency fee charged by the third party platform might degrade the net revenue of the buyer. Against this background, we try to study the social diffusion mechanisms over a graph. The connections modeled in the graph might represent positive individual interactions, which have been widely adopted for information diffusion, information acquisition, and information search. With the local positive interactions, social diffusion mechanisms can bring a volume of potential sellers without any extra cost. Taking the buyer's budget constraint into account, the following natural question arises:

Can we design a budget-feasible mechanism which guarantees desirable economic properties and stimulates involved sellers to propagate auction information to her neighbors over graphs, while guaranteeing a bounded total payment from the buyer?

Example. Considering the questionnaire, a classic research instrument for the organizer to gather information from respondents especially in the social networks, a critical requirement is to get sufficient respondents. However, it is inefficient and costly for the organizer to notify all respondents by herself. A promising way is to incentivize participated respondents to invite potential people, *e.g.*, their followers and friends. There may be costs associated with finishing questionnaires, *e.g.*, participants' time and privacy. It is common to give participants monetary rewards to motivate the population. Moreover, the organizer usually has a budget and cannot afford unlimited monetary rewards. Therefore, such scenario calls for viable budget feasible diffusion mechanisms.

In the information diffusion mechanism design literature, all critical participants whose invitations increase social welfare will be rewarded [1, 2, 6, 7]. Existing diffusion mechanisms mainly focus on seller-centric auctions where the seller incentivizes buyers to diffuse the information and decides the final winners. While in budget-feasible mechanism design, as a fundamental difference from the seller-centric auction, the payment used to elicit truthful behaviour should satisfy the buyer's budget constraint. The payment scheme used to elicit truthfulness or propagate the auction information

in seller-centric auctions cannot meet the budget-feasibility requirement in reversed auctions as an unbounded payment may be incurred.

1.2 Budget Feasible Mechanism with Fair Representation

Selecting a proper number of agents from each group to proportionally represent the population of each group has received increasing attention in recent years. For instance, selecting a committee consisting of members from different groups or hiring workers of diverse attributes requires making selection decisions on a given set of population. Fair representations can also be applied to the context of the political poll or survey sampling in which the organizer wishes to obtain a diverse set of responses from various groups of populations. Moreover, inadequate group representation can affect generalisability in real applications (*e.g.*, inaccurate poll predictions due to lack of representative samples) and inequality (*e.g.*, group inequality when hiring workers).

In addition to the challenge of achieving proportional representation, in many settings, there is an inherited private agent cost associated with each selected agent (*e.g.*, salary in job hiring or cost for participating in the survey) and the private cost is not visible to the social planner. Ideally, the planner elicits cost information from the agents, determines the agents to select, and derives appropriate compensation or payment to the selected agents. However, the agents can be strategic and do not necessarily report their true costs. As a result, the social planner must decide whom to select to represent groups, while taking agents' costs into account to ensure that the total payment to all agents does not exceed the given budget (*e.g.*, the budget for hiring the agents or conducting the survey studies).

The problem in hand can be cast naturally into a budget-feasible mechanism design setting [5] where the social planner seeks for a computationally efficient mechanism that elicits true cost information from agents, selects representative agents to represent each group proportionally, and ensures that the total payment to the agents is not more than the allowable budget. More specifically,

Can we design a budget-feasible mechanism which selects agents from different groups proportionally and guarantees desirable economic properties, while guaranteeing a bounded total payment from the planner?

Existing budget feasible mechanisms do not perform well for these settings directly as they do not consider groups and ensure proportional representation. In particular, these mechanisms greedily select agents with the lowest cost-per-value ratios irrespective of the group memberships, which may lead to the selected agents belonging to one group only if a similar greedy manner is used in the group setting (*e.g.*, all the members in a single group have very low cost-per-value ratio). Thus, such a mechanism cannot ensure proportional representation.

1.3 Budget Feasible Mechanism in Two-sided Markets

For one-sided markets, either with a single-seller and multiple buyers or with a single-buyer and multiple sellers, much research effort in the past decades has been invested to design auction mechanisms to regulate the trading. While for two-sided markets with both buyers and sellers being strategic, most of the works fall into the research line of double auction mechanism design ([3, 4]), which assumes that the sellers can bid their costs and the buyers can bid their values for the items and the mechanism needs to determine the trading/payment rules that guarantee some desirable properties, such as truthfulness of the bidding behavior. In such scenarios, buyers' behavior and sellers' behavior are somehow symmetric, one with item value and one with item cost. Accordingly, the seminal work in [3] provides algorithms to match buyers to sellers by natural ordering of their values until a breakeven index;

These works, however, did not provide truthful mechanisms for a natural procurement scenario in two-sided markets where multiple strategic buyers come into the market with their private *budgets* and want to procure as much value of items as possible from the sellers with private costs. A mechanism in such scenario needs to guarantee that the total payment paid by each buyer does not exceed its own budget. In such scenario, the behaviours of buyers and sellers are asymmetric, and the main challenge in designing such mechanisms differs much from the traditional double auctions that does not consider payment budgets. A natural question then arises in such scenarios.

Can we design an efficient mechanism in two-sided markets that stimulates the desired economic interactions among buyers and sellers without any buyer's payment exceeding its budget?

Example. In the crowdsourcing markets, there may exist multiple requesters who want to procure services from users, *e.g.*, sensing data and image label. When participating in the crowdsourcing markets, users are required to contribute resource consumption, e.g., computational resources, time and expose themselves to potential privacy threats by sharing their personal data. For this reason, it is important to design an efficient incentive mechanism to stimulate users to contribute to the markets. In addition, costs of users are privately known by themselves and requesters have budgets which limit the total payment of obtained services. Therefore, such scenario calls for two-sided viable budget feasible mechanisms.

In the procurement mechanism design problem above, multiple buyers compete with each other for procuring more value of items with diverse procurement budgets/abilities and the sellers compete with each other to sell their items with more payment rewarded. The designed mechanism should determine an allocation and a payment scheme to guarantee various desired theoretical properties like, *individual rationality* that the payment to each seller covers at least (but not necessarily equals) its private cost, *budget feasibility* that the total payment of each buyer does not exceed its budget, *sellers' truthfulness* that no sellers have incentive to bid a false cost, *buyers' truthfulness* that no buyers have incentive to claim a false budget, and *approximation* that the total value procured by buyers is close to the optimal solution that would be achievable had the mechanism known the bidders' true private information.

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