A Study of Limited-Precision, Incremental Elicitation in Auctions: Extended Abstract

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1. Introduction

Day-to-day business transactions have come to rely on the computer networks that link market participants by providing fast, seamless communication and negotiation channels. This move to online negotiation has led to the development of more and more sophisticated software agents that mediate such transactions. However, since the interests of the parties on whose behalf such agents act generally conflict, ideally such agents should reason strategically according to the well-studied principles of game theory and economics. As such, recent research in computer science and economics has focused on the design of economic agents and the mechanisms through which they interact.

Mechanism design [3] has played a central role in much of this research. Recently, limitations of standard approaches to mechanism design have been identified, and are starting to be addressed. Chief among these is the computational complexity of the problems faced by interacting software agents. For instance, mechanisms based on the revelation principle must reveal their type (often, the utility function) accurately. This presents a problem in circumstances where utility functions are large and difficult to communicate effectively and/or hard to compute accurately. Recent research has begun to examine methods involving limited or incremental elicitation of types to circumvent some of these difficulties [1, 2, 5, 4], specifically in the context of (single-good or combinatorial) auctions.

In this paper, we pursue the same line of research. Specifically, in the context of single-good auctions, we analyze mechanisms that allow bids with *limited precision* and that elicit bids by allowing bidders to sequentially refine their bids. We propose various natural constraints on such incremental mechanisms and show that any mechanism satisfying these constraints, and having *dominant strategy equilibria*, must have a very restricted form. We then present one sample mechanism of this form and show that it can be optimized for various social objectives.

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2. Incremental, limited precision mechanisms

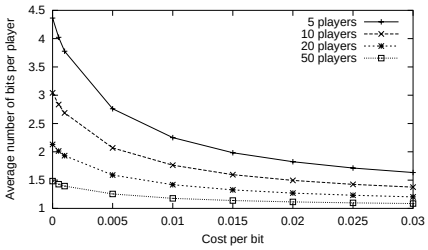
While single-shot mechanisms can be used to achieve the objective of limiting both communication and revelation [1, 2], they are not very flexible in the following sense. Many agents may reveal much more about their valuations than is required to determine the desired outcome. For example, if k bits of precision per player is used, we may easily be able to rule out many (or most) bidders as potential winners with far fewer than k bits.

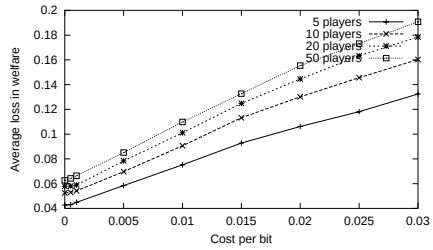
We consider direct, incremental mechanisms for the allocation of a single good. Incremental here implies an iterative mechanism in which each move is viewed as providing some information about the player's valuation by *refining* the information revealed earlier. We restrict the class of mechanisms as follows: (1) At each round t an agent can potentially reveal one message from the feasible message set M^t. (2) Finite message sequences are comparable. (3) The mechanism is fully deterministic (i.e., a good is never allocated randomly). To formalize this we assume that the auction terminates at iteration t with allocation only if t is such that some bidder has specified a unique greatest message sequence. The good is allocated to that bidder. (4) We assume quasi-linear utility and *ex post* rationality. As such, only the winner makes a payment.

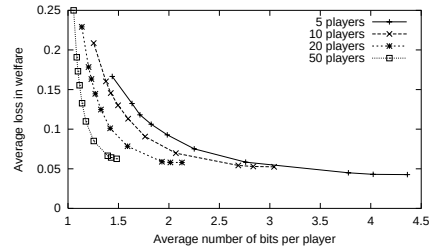
First we show that all single-good, incremental auctions satisfying the above conditions and having *dominant strategy equilibria* must belong to the class of *increasing price mechanisms*. Such a mechanism requires, for any player i, the following: if we fix moves of her opponents, let t be the earliest round at which i could win and let τ be the price paid by i at round t (against these fixed opponents) should i choose a strategy that wins at t; then τ must be no more than the price paid if i wins at any later round against the same opponent moves.[1]

To limit the amount of communications and revelation we introduce the *limited participation* restriction. We say

1 The space of increasing price mechanisms contains *ascending price mechanisms.*







that an incremental mechanism *limits participation* iff no player is allowed to participate once her utility function has been refined to the extent necessary to permit optimization of the mechanism's objective. In our limited-precision auction setting, this corresponds to the following activity rule: a player remains *active* as long as her message sequence is at least as great of any other bidder. Under this restriction we show that for any player *i*, dominant strategy σ_i and any vector of other players' strategies σ_{-i}: if σ_i wins against σ_{-i} when played with valuation v_i, then any other dominant strategy for *i*, when played with valuation $v'_i \geq v_i$, must win at the same iteration and with the same payment.

Based on this result we show that for any *i*, v_i, σ_i and σ_{-i} (defined as before), if player *i* remains active at iteration *t* and it is possible for *i* to *profitably* win after *t*, then any other dominant strategy of *i* for any valuation $\geq v_i$ must be equivalent to σ_i up to iteration *t* (given the same history). This implies whenever a player is active and the current iteration is not the last iteration where she can profitably win, the player does *not* need to state a bid, but only to announce an intention to participate. Therefore, it is sufficient to consider the mechanisms that in most situations restrict the players' actions to just two choices.

3. Example and Results

We present an adaptive symmetric incremental auction (ASIA) mechanism that satisfies the above properties.[2] ASIA operates as follows, initially all players are declared *active*. At iteration *t*, the mechanism announces a price p^t to all active players, $p^t \geq p^{t-1}$. Every active player reveals either 1, indicating willingness to purchase the good for p^t, or 0, which makes the player inactive. The mechanism terminates if there is only one player reporting 1 (receives the good) or all players are reporting 0 (the good is not allocated). ASIA has a dominant strategy equilibrium in which every player *i* with valuation v_i bids 1 at iteration *t* as long as $v_i > p_t$ and 0 otherwise. This dominant strategy is independent of the actual prices, as long as the sequence is non-decreasing. We use this fact to optimize the price levels for various social objectives, assuming a known prior distribution over the players' valuations. We solve a Markov decision process to find the best pricing policy.

The above graphs demonstrate the performance of ASIA based on optimized policies. The first shows that an expected amount of communication decreases as cost increases. The second graph demonstrates the relation between communication cost and the loss in welfare, while it suggests that ASIA fares worse with increasing numbers of players, we can recast our results by considering loss in welfare as a function of the amount of per-player communication. The last graph shows that in fact, with more players ASIA requires *less* per-player communication to achieve the same loss in welfare. This demonstrates the advantage of incremental mechanisms with limited participation over one-shot mechanisms which, with fixed precision, usually fare worse with more players.

4. Concluding Remarks

We have proposed a class of incremental, limited-precision auctions with limited participation. The proposed mechanisms have simple form, dominant strategy equilibria, and can be optimized to account for communication and computational costs. Empirical results suggest that such mechanisms can find near-optimal allocations with very little communication, and offer advantages over one-shot auctions. We have recently extended ASIA to a stochastic model that is optimal w.r.t. social welfare, but can be optimized similarly to ASIA.

References

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2 The rules of this auction are similar to the rules of Japanese auction.

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