Pick-A-Bundle: A Novel Bundling Strategy for Selling Multiple Items within Online Auctions

(Extended Abstract)

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ABSTRACT

In this paper, we consider the design of an agent that is able to autonomously make optimal bundling decisions when selling multiple heterogeneous items within *existing* online auctions. We show that while bundling the items together into a single lot is effective at reducing listing costs, it also results in a loss in auction revenue. To address this loss we introduce a novel bundling strategy, that we call *pick-a-bundle*, that can be implemented within any existing auction format. We show, mainly using simulations, that this new bundling strategy generates greater expected revenue than the complete bundle of all items, and, by inducing additional competition between bidders, it usually generates greater expected revenue than using separate auctions for each item. In order for our agent to accurately and efficiently calculate its expected revenue when using our new strategy, we derive a novel polynomial time algorithm for calculating the probability distributions of the sum of the top order statistics of i.i.d. variables drawn from any arbitrary distribution. Furthermore, we include in our analysis the strategic behaviour, in terms of bid shading, that the buyers may consider in our new auction format.

Categories and Subject Descriptors

I.2.11 [**ARTIFICIAL INTELLIGENCE**]: Intelligent Agents

General Terms

Theory, Economics, Experimentation, Algorithms

Keywords

auction, multiple items, bundling, revenue

1. INTRODUCTION

The bundling of a number of heterogeneous items into a single lot is a common strategy when sellers participate in auctions. For example, within an online auction, such as *eBay.com* or *taobao.com*, sellers may bundle together a small number of low cost items, such as DVDs or computer games, in order to avoid incurring separate listing fees. Likewise, in traditional auctions it is common to find furniture items bundled together into a single lot in order to reduce the time overhead (and cost) involved in selling each item separately.

While the cost saving of bundling items together is self-evident in the examples described above, these savings must be set against the effect that bundling has on the expected revenue of the auction. Specifically, when the items being sold exhibit complementary valuations (i.e. the valuation of the bundle is greater than the sum of the valuations of each individual item) then the rationale for bundling is clear. However, the formal economic literature has little to say regarding the seller's revenue when bundling items that exhibit non-complementary valuations within auctions (as in the example of a bundle of DVDs described above). In particular, research in this area has so far only addressed the problem faced by a multi-product monopolist offering single items or bundles of items at fixed prices [1, 10]. While this setting is somewhat different to the one that we consider, this work shows that the bundling of goods can yield an increase in revenue, even when the items offered exhibit non-complementary valuations. Similarly, more recent work on the bundling of information goods on the internet, again shows profitability even in the absence of network externalities or economies of scale [2, 3]. Jehiel *et al.* [2007] examine a setting with additive valuations, which is similar to ours, however as the authors point out in their conclusions, their results do not work within "standard auctions". This limitation is also present in the computer science literature, where the bundling of items is often studied within the context of combinatorial auctions (see [5] for a review). Furthermore, this work has largely addressed the issue of complementary valuations, and has proposed novel auction protocols that allow bidders to express their preferences for specific bundles of goods [11, 4, 6, 9]. While such results are useful to the designers of new online or real-world auctions, they do not help a seller who is attempting to use an existing auction format (such as the English auctions of eBay or the sealed bid second price auction) in which bidders may only submit bids on the lot offered (and not on subsets of items).

Against this background, in this paper we consider for the first time the effects of bundling non-complementary goods *within a standard auction format*[1]. Our goal is to develop an autonomous *auction agent* that can advise on, and ultimately automate, the process of selling multiple heterogeneous items within such online

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[1]We specifically consider a sealed bid second price auction in our analysis, but due to the revenue equivalence theorem, our results apply to any efficient auction protocol.

auctions. To this end, we present a novel bundling strategy, that we call *pick-a-bundle*, in which a seller lists a set of items and announces a bundle size, and the buyers bid for the right to select a number of items from this set, which is equal to the bundle size;[2] the remaining items, which were not selected by the winner in his bundle, are then sold in a second round of separate auctions. For example, five DVDs may be listed and a bundle size of three might be announced, thus the winner of the auction would select the three DVDs that he would like to receive and the remaining two would be sold in a second round of separate auctions afterwards.

The design of our pick-a-bundle auction is informed by the intuition that bundling items will in general reduce the transaction or listing fees of the seller, but by offering just a subset of the items to the buyer, it will also induce competition between bidders who may actually prefer different items. This second factor has been observed in real world auctions that are sometimes used to sell a number of individual apartments within an apartment block. Here, rather than bidding for individual apartments, the buyers bid for the opportunity to select one of the remaining remaining unsold apartments. This procedure generates competition between bidders who prefer different apartments, and results in increased revenue for the seller [Personal communication from Michael H. Rothkopf, 2007]. We show that the same factors influence our pick-a-bundle auction, and that it generates greater expected revenue than an auction selling the complete bundle, and than selling each item in separate single-item auctions. Thus, in more detail, this work makes the following contributions:

- Initially, we propose our novel pick-a-bundle format. Contrary to pre-existing work on bundling, *this format can be implemented within any existing standard auction*, as it does not require a redesign of the auction.
- We then examine how buyers bid in our new format. While in some cases, the bids will not be affected, in some others the buyers are going to shade (reduce) their bids. This occurs because of the presence of the second round of auctions, which give the opportunity to buyers who did not win the pick-a-bundle auction, to purchase the items that were not sold as part of the bundle in the first round. We include these results in our analysis.
- Furthermore, we prove theoretically that pick-a-bundle (for bundle size $k = 1$) will outperform separate auctions, which was the best previous option. We prove this for any setting where there is no bid shading, and also, generally (when bids are shaded), for the case when the items are similar.[3] We also discuss why this last result holds even in the case of dissimilar items.
- After that, we examine finding the optimal bundle size k. Even though size $k = 1$ outperforms separate auctions, it is not necessarily the best size. To compute the expected revenue obtained by using the various auction formats in the most general setting, it is necessary to conduction simulations. As these scale poorly as the size of the problem (i.e. the number of items and bidders) increases, we develop a novel polynomial time algorithm for calculating the probability distributions of the sum of the top order statistics of i.i.d. variables drawn from arbitrary discrete distributions,[4] which is used to compute the expected revenue without simulations, for the case of similar items. Finally, we present some representatives of the many experiments we conducted. All these experiments show that the pick-a-bundle format increases the seller's revenue, even when savings in listing costs are not considered, and thus reinforce our theoretical results.

[2]The idea of choosing the top valued items has also been used in [8, 12]. However, in these settings, the prices are fixed. Furthermore, information goods can be copied, whereas in our setting the fact that the bidders are competing for limited unclonable resources is what creates additional revenue.

[3]We assume that all the times have the same prior distribution from which valuations for the items are drawn. Our motivating example of a seller selling a number of DVDs on eBay falls in this case.

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[4]This algorithm can also be used in a variety of other settings, e.g. to compute the distributions of (i) the revenue that a seller makes in a position auction (Google Adwords is a variation of a position auction) from the distributions of the bids, and (ii) the social welfare (sum of winners' valuations) in a multi-unit auction.