Revenue Maximization via Hiding Items Attributes

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Abstract

We study probabilistic single-item second-price auctions where the item is characterized by a set of attributes. The auctioneer knows the actual instantiation of all the attributes, but he may choose to reveal only a subset of these attributes to the bidders. Our model is an abstraction of the following Ad auction scenario. The website (auctioneer) knows the demographic information of its impressions, and this information is in terms of a list of attributes (e.g., age, gender, country of location). The website may hide certain attributes from its advertisers (bidders) in order to create thicker market, which may lead to higher revenue. We study how to hide attributes in an optimal way.

Introduction

- One advantage of Internet advertising is that it offers advertisers the ability to target customers based on various traits such as demographics. As a result, advertisers generally only win (impressions from) visitors that they aim to target. On the other hand, this may reduce the revenue received by the auctioneer (publisher, e.g., website) due to the thin market problem: there may be few competitors for some contexts. Actually, if for every context, there is only one advertiser interested in it, then the total revenue is **0** under the standard second-price auction. The main goal of our work is to extract more revenue for the auctioneer by allowing targeting, but at the same time avoid the thin market problem.

Model

- There are $\mathbf{n}$ bidders.
- The auctioneer has a single item for sale (an ad slot in a website).
- The item is characterized by $\mathbf{k}$ attributes $\mathbf{a_1, a_2, \ldots, a_k}$ (e.g., location, age, gender).
- Attribute $\mathbf{i}$ has $\mathbf{C_i}$ possible values, so there are $\mathbf{m} = \prod_{i=1}^{k} \mathbf{C_i}$ instantiations.
- An instantiation is chosen randomly by nature, according to a common knowledge distribution $\mathbf{p} \in \mathbf{\Delta(m)}$.
- Auctioneer sells the instantiation via a $\mathbf{2^{nd}}$ price auction.

Information asymmetry

The bidders know only the probability that each instantiation is chosen, but the auctioneer knows the actual realization for the item.

How can the auctioneer use this to extract more revenue?

Natural bundles

- [Ghosh et al. 2007], studied the idea of increasing revenue by bundling different instantiations together. We observe that in practice, Ad impressions are categorized based on multiple attributes. Given this, we argue that the most natural way to bundle is by hiding attributes. For example, let there be three attributes, each with two possible values:
  - Age: Teenager, Adult
  - Gender: Male, Female
  - Location: US, Non-US
- There are $\mathbf{2^3}$ possible instantiations. Under previous studies, the website is allowed to hide information by bundling any subset of instantiations like {(Teenager, Male, US), (Adult, Female, Non-US)}. By creating this bundle, the website basically may tell the advertisers that a visitor is either a teenage US male or an adult Non-US female, which does not appear natural.
- Attribute hiding always leads to natural bundles. For example, the website may hide the location attribute. That is, if the actual instantiation is (Teenager, Male, US), then the website may inform the advertisers that the visitor is a teenage male and create the bundle (Teenager, Male, **?**), which consists of both (Teenager, Male, US) and (Teenager, Male, Non-US).

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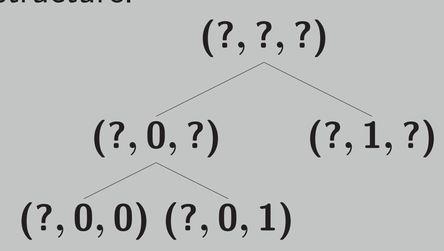
Natural signaling

1. The auctioneer a-priori declares a partition for the set of instantiations into bundles such that:
   - The bundles are only natural bundles (bundles of instantiations resulting from hiding some attributes).
   - Each instantiation is exactly in one bundle.
2. Once an instantiation is randomly chosen, auctioneer reveals the bundle that contains the item.
3. The bidders submit their bids.
4. The bidder with the highest bid wins the instantiation and pays the second hignest bid.

Results so far

- It is **NP-hard** to compute the optimal signaling scheme, even if all attributes are binary ($\mathbf{C_i = 2}$ for all $\mathbf{i}$).
- If every bidder has positive value equal to 1 for only one instantiation and all attributes are binary, then the problem can be solved by matching.
- If every bidder has positive value equal to 1 for only one instantiation and each attribute has eight possible values, then it is **NP-hard** to compute the optimal signaling scheme.
- We proposed two heuristic algorithms
  - The first one is based on weighted matching and it can be applied only if all attributes are binary.
  - The second uses dynamic programming and produces a signaling scheme that has tree-structure.



- Experiments

Setup	Tree	Match	UB	#Opt
$\mathbf{k = n = 3}$, $\mathbf{\bar{C} = 2}$	13.33	11.58	15.42	47
$\mathbf{k = n = 5}$, $\mathbf{\bar{C} = 2}$	3.953	3.810	4.354	35
$\mathbf{k = n = 10}$, $\mathbf{\bar{C} = 2}$	0.836	0.927	0.950	0
$\mathbf{k = n = 3}$, $\mathbf{\bar{C} = 3}$	9.251	NA	10.58	25
$\mathbf{k = n = 5}$, $\mathbf{\bar{C} = 3}$	1.767	NA	1.976	0
$\mathbf{k = n = 8}$, $\mathbf{\bar{C} = 3}$	0.296	NA	0.361	0

Comparing to selling all instantiations separately, the extra revenue in terms of percentage. **Tree** is for the algorithm that produces a tree structure, **Match** is for the weighted matching algorithm and **UB** is the upper bound for the optimal revenue. **Opt** is the number of times out of 100 simulations that at least one heuristic algorithm reaches the upper bound.

Future research

- Approximation guarantees for the heuristic algorithms
- Heuristic algorithms for the bayesian case, where the auctioneer does not know bidders' valuations
- Asymmetric signaling: The auctioneer sends a different signal to every bidder.

References

[1] Mingyu Guo and Argyrios Deligkas (2013).
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