A Quantization Procedure for Bilevel Pricing Problems with an Application to Electricity Markets

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1 Introduction

Electricity retail markets are now open to competition in most countries, and providers are free to design a menu of offers/contracts in addition to regulated alternatives (fixed prices), so that each consumer can select among the vast jungle of offers the one which maximizes his utility. In this context, the choice of a contract made by the consumers is based on the minimization of the invoice (rational choice theory).

A standard approach consists in constructing an *incentive-compatible* menu of contracts, i.e., a menu composed of as many contracts as customers, where each contract is especially adapted to a specific customer, taking his type into account. However, in reality, an electricity provider aims to design an optimal menu of offers, maximizing the revenue, under a restriction on the "size" of the menu (number of contracts). With less contracts than consumer's types, the decision of the customers is of a combinatorial nature: for a given size of menu, the problem can be modeled by a bilinear bilevel problem, in the same vein as the product pricing problem [3]. This bilevel problem is usually solved by Mixed Integer Linear Programming (MILP) approaches through single-level reformulation, see e.g. [2], but is highly difficult to solve to optimality for a large number of consumers (followers).

2 Solution approach

We show that the question of limiting the number of offers can alternatively be viewed as an optimally quantized version of the full-size solution (incentive-compatible menu), the latter one being computed a priori by a convex variational problem, see e.g. [4]. The quantization problem is similar to the pruning problem that appeared in the max-plus based numerical methods in optimal control. This problem has been proved to be NP-Hard, and we develop here a new quantization heuristic, which, given an initial menu of contracts, iteratively prunes the less important contracts, to construct an implementable menu of the desired cardinality, while minimizing the revenue loss.

We apply this algorithm to solve a pricing problem with price-elastic demand, originating from the electricity retail market. Numerical results show an improved performance by comparison with earlier pruning algorithms.

This talk is based on a preprint [1].

References

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