Dynamic Mechanism Design for Online Commerce

Assistant Professor Jérémie Gallien

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Executive Summary
Prepared by: Heather Snow

Overview

One of the fastest growing areas in e-business is the use of online auctions for B2B and B2C transactions. However, associated with the increasing use of online auctions for business transactions is the awareness of the time inefficiencies inherent to the bidding process. Because time is money, it is necessary to take into account the value that buyers and sellers place on time in order to determine the appropriate mechanism for revenue maximization.

Mechanism Design Theory is a branch of microeconomics concerned with the design of market rules maximizing revenue for situations in which economic agents have private information that they will use strategically (such as auctions). Mechanism Design Theory enables researchers to operate without pre-existing postulates or assumptions and to instead derive the optimal market rules endogenously.

However, most of the research to date on Mechanism Design has ignored the timing of transactions and bidder arrivals. In many e-commerce situations, buyers do arrive sequentially and both buyers and sellers do care about waiting time. Extending previous work in Auction and Search Theory, Gallien proposes a formulation for the problem of maximizing expected time-discounted revenues when selling multiple identical items to a stream of time-sensitive, self-interested potential customers. Within this framework Gallien derives the optimal dynamic mechanism, and conducts numerical simulations to compare its performance with that of other commonly used dynamic mechanisms such as online catalogues and auctions.

Model

Previous work in this area assumes that the selling mechanism begins in a room at a specific point in time with all bidders present. Each bidder has his or her own private valuation (the maximum that one would be willing to pay), and nobody knows what the others’ valuations are, thus creating an information asymmetry which is one of the key aspects of the model. The optimization problem is this: from the perspective of the seller, given the market environment, what is the optimal mechanism (allocation and payment rules) for selling the good in order to maximize expected revenue, i.e., who will get the good and at what price? Auction Theory predicts that the optimal mechanism in this environment is a standard auction with an appropriate reserve price. However, this model does not capture the element of people’s concern for time.

In Gallien’s model, bidders are not assumed to all be initially present, but rather are expected to arrive in a random stream staggered over time, e.g. following an online product launch. The objective is for the seller to maximize the discounted revenue (gross revenue reduced by a factor taking waiting time into account). In modeling the utility and behavior of buyers and the seller
interacting in this exchange, Gallien captures the disincentive associated with waiting (the value individuals place on their time). The time period in this model is not specified, and the optimal stopping time (time when the sale should occur) is one of the key elements to the optimization problem. Gallien also factors into the model the self-interested, economically rational behavior of bidders.

Gallien provides the theoretical solution to this problem, namely a fixed price mechanism (e.g. an online catalogue), but where the price is determined by taking into account not only the distribution of bidders’ valuation (maximum price they are willing to pay for the item), but also the distribution for the number of bidders arriving over a given time period. In addition, his analysis generates a simple equation from which the exact value of the optimal price can be readily computed.

To assess the likely performance of this selling procedure in practical situations, Gallien conducted numerical simulations, whereby he generated thousands of streams of virtual bidders and compared the revenue generated by both auction and fixed price mechanisms. He performed these simulations under different conditions by varying interest rates (equivalent to the value placed on time), and measured the discounted revenue, revenue volatility, and robustness (the level of sensitivity the outcome of the mechanism has to variations or inaccuracies in the data) for each.

As predicted by his theory, the results demonstrate that in all cases the optimal fixed price is superior to the optimal auction in terms of expected discounted revenue (i.e., when taking the value of time/interest rate into account). Furthermore, the relative superiority of the optimal fixed price mechanism over the optimal online auction increases with the interest rate/value placed on time. However, fixed price mechanisms tend to be less robust than auctions at low interest rates, meaning that the revenue obtained with a fixed price mechanism is more sensitive to inaccuracies in the data/parameter estimation errors. Therefore in low interest rate situations, the slight revenue advantage of using fixed price mechanisms is outweighed by the greater robustness of auctions.

In conclusion Gallien prescribes a basic principle for practitioners: in situations when the value placed on time is high, revenue maximization is best achieved by using a fixed price mechanism; in situations when the value placed on time is low, the auction is a preferable option (unless the model parameters, including valuations, bidder arrival rate and interest rate, can be estimated with great accuracy).

**Future Applications**

Gallien’s model can be applied to any B2C or B2B situation in which a company is wondering whether it should use an auction or a fixed price method such as an online catalogue to sell products or services. The model may also be especially useful for financial institutions, as the revenue they derive from selling their products is directly tied to interest rates. Gallien is currently working on adaptive pricing mechanisms, where the market parameters (valuations, arrival rate) are dynamically estimated as demand is progressively being observed.

**About the Researcher**

Jérémi Gallien is an Assistant Professor in the Operations Management Group at Sloan. He works on the formulation and analysis of quantitative models for business decision-making, particularly in the areas of Pricing and Revenue Optimization and Scheduling and Procurement. He also designs smart market mechanisms and optimization-based auctions for e-Commerce, and is the Co-Founder of a software company that specializes in developing e-Commerce applications.