The Infonomics Workshop on Electronic Market Design

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The Infonomics Workshop on Electronic Market Design took place in Maastricht, The Netherlands from July 11th until July 13th, 2001. The workshop contained 25 presentations about computational, economic, and game-theoretic aspects of electronic market design. This report summarizes the program.

Categories and Subject Descriptors: F.2.1 [**Theory of Computation**]: Analysis of Algorithms and Problem Complexity—*Numerical Algorithms and Problems*; J.4 [**Computer Applications**]: Social and Behavioral Sciences—*Economics*

General Terms: Combinatorial Auctions

Additional Key Words and Phrases: Economics, Mechanism Design

1. INTRODUCTION

With more and more firms using the Internet for selling and purchasing goods, the design of trading mechanisms becomes one of the most important issues in electronic commerce research. Economic theory has created a great deal of knowledge about markets, and how market design may influence prices and welfare. With emerging electronic markets there is the potential for this knowledge to inform as well as explain the design of markets. Taking the argument a step further, we see an increasing number of mechanisms for information exchange, interaction and coordination between human and software agents contributing to a complex, digital environment of individuals and companies. Designing the environment as a common good needs a level of insights in mechanisms that is not available in the economic literature.

Implementations of market mechanisms can rely on an amount of information exchange and processing that was not feasible before. Nevertheless they face the

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limitations of computability when their rules require the solution to NP-hard optimization problems. The complexity of such mechanisms has attracted the attention of computer scientists and mathematicians from the field of combinatorial optimization. But even a computationally efficient mechanism that implements a well understood economic design may not lead to the predicted outcome. Indeed, human agents may show limited rational behavior, or base their decisions on exogenous criteria. For this reason an analytical investigation of market mechanisms is not sufficient, testing them with human subjects is crucial. Human agents may want to express bounded rationality in terms of computational prescriptive models for software agents acting on their behalf. The interaction between incentives and the software agent's limited computational capability is an issue again.

The problem of mechanism design is how to allocate resources amongst agents, so as to optimize some performance criterion, when the values of those resources are private information to the agents themselves. Allocations of the resources may or may not be compensated by payments. Example optimization criteria are revenue maximization for agents with object endowment or maximization of total welfare. The optimization could be subject to constraints such as fair distribution or budget constraints. Several dimensions may be used to classify the design problem. The first is the complexity of the underlying resource allocation problem with full information, like the number and characteristics of the resources, whether they are homogeneous or heterogeneous, and whether the initial endowment is with one or several agents. Related to this is the structure of the bidders' valuations for bundles of objects, including whether types are additive or not, non-zero for all but a polynomial number of bundles, private, interdependent or symmetric or not, etc. A third dimension is the complexity of constraints, determining which allocations are considered to be feasible. A fourth dimension describes the goals of the design. Should bidders have dominant strategies, is truth-revelation a target of the design, etc.? A fifth dimension is the complexity of decision-making and communication, as well as the division of computational effort between principal and agent.

A range of disciplines has done research on mechanism design and has made contributions to different areas in this space. Strengths and weaknesses of their specific scientific approach leads to a focus on particular aspects of mechanism design. Auction theorists have focused on the incentive issues with less deference to the computational ones. Computer scientists have been attracted by the well-defined computational problems that form the core of economically efficient private values auctions. Recently there is starting to develop a body of research that integrates computational concerns with incentive issues. One example has been to ask how close to full (economic) efficiency can one get with incentive compatible but computationally efficient mechanism? A second example is to relate ascending auctions with good incentive properties to known classes of optimization algorithms.

The Infonomics workshop on Electronic Market Design, which took place in Maastricht from July 11-13, 2001, brought together researchers from economics, computer science and operations research to discuss such issues. Members of the programme committee were Eric van Damme, Daniel Lehmann, Tuomas Sandholm, Rakesh Vohra and the second author. The latter is very grateful for the support of the others to develop an agenda for the workshop and to encourage so many excellent researchers to come to Maastricht. In the following we give a

brief summary of the 25 presentations given by the invited speakers. As some speakers presented work in progress and others gave an overview of their recent papers, we list neither titles of papers nor co-authors. Most of the abstracts, and in some cases also links to papers, can be found on the workshop website `http://www.etrade.infonomics.nl/workshop`.

2. AUCTIONS IN ACTION

In these sessions, implementations of auctions were discussed. Charles W. Polk presented the solutions developed by Net Exchange(TM) for implementing combinatorial auctions, which have been applied in logistics, financial, power and chemicals markets.

Jayant Kalagnanam discussed direct procurement auctions implemented by IBM, in which buyers in effect specify the price curve (volume discounts) they want.

Benny Moldovanu talked about the implementation of several UMTS license auctions in Europe and concluded that Industrial Organization research into the structure of the market is essential in designing successful auctions. A plea for leveling the playing field by Europe-wide allocation schemes was also made.

Noam Nisan presented MAJIC (Multi-parameter Auction for Jini Components). This is an implementation of a new general-purpose architecture for applying economic mechanisms for resource allocation in distributed computer systems. A key novel aspect is that it handles multiple parameters in the allocation and in the specification of utilities and costs for each distributed service.

Marcel Roelofs presented multiagent technology in AIMMS, which is a system for modeling and solving decision problems. AIMMS may be used as a framework to create communities of optimizing agents.

Tuomas Sandholm presented in the first part an overview of papers on clearing algorithms for bundle auctions. They showed how large improvements in the performance of these algorithms had been achieved in the last 3 years. The second part of the presentation was on how bidding agents in combinatorial markets should behave when they have limited computational resources for strategic decision making.

3. MARKET DESIGN

Ronald Harstad presented results on how to sell a continuum, like the ad space around a sports field. In the case of a one-dimensional space of bidder types, no externalities, and single peaked preferences, splitting the continuum into approximately one block per 2 bidders maximizes revenue. His auction yields higher revenue than VCG, but as the number of bidders grows, the two mechanisms asymptotically obtain the same results.

Rakesh Vohra, motivated by the California power exchange, presented research into auctions for procuring options. Reformulating these auctions as flow networks one obtains VCG prices as dual variables of the LP.

Dov Monderer talked about the efficiency of probability independent equilibria in combinatorial auctions, and analyzed the tradeoff between economic efficiency and computational efficiency.

Peter Wurman presented investigations into anonymous-price, progressive combinatorial auctions. In a recent paper they showed that under the assumption that only buyers may choose the best bundle, anonymous price equilibria always exist.

Jacob Goeree discussed Anglo-Dutch auctions with an endogenous reserve price. After an ascending part, the last two remaining bidders make a closed bid. Due to a special feature whereby the second highest bidder gets a side payment for raising the price in the Dutch part of auction, the expected revenue is higher than that obtained by a straight English auction, even in auctions where the winner is a-priori clear.

Ahuva Mualem constructed mechanisms for restricted auctions that are strategy-proof, even though they only approximate the NP-complete winner determination problem. Interesting is her approach to combine truthful mechanisms into one, thereby getting better approximations than each algorithm would yield on its own.

Kevin Leyton-Brown presented CATS 2.0, (Combinatorial Auctions Test Suite 2.0), and suggested ways to include incentives in future, possibly commercial, peer-to-peer networks. He also discussed mechanisms for setting up bidding clubs in combinatorial auctions, and showed that these bidding clubs can be used to transform one mechanism into another.

4. COMPLEXITY AND WINNER DETERMINATION

Subhash Suri presented a detailed analysis of the complexity of market clearing in multi-unit double auctions, when buyers and sellers submit quote functions.

Andreas Schulz revisited questions of the complexity of the winner determination problem, observing that it is the communication of types, rather than the computation of the wining bids that makes the Vickrey Clarke Groves mechanism intractable. The second part of the presentation analysed the question how well decentralized decision making is able to approximate the best central decision.

Two papers were presented on fast and exact algorithms for the winner determination problem in combinatorial auctions. Both were tested on well-known test cases. Rica Gonen showed that linear programming helps solving large[1] multi-unit combinatorial auctions if used as a bound in branch and bound search: their algorithm has sub-exponential growth in the number of bids. Andrew Gilpin presented CABOB, a fast optimal algorithm for combinatorial auctions. Here also, LP is so tight that it is worth using it, even if it is slower than other branch and bound bounding methods.

Marta Esö talked about an algorithm approximating the optimal winner in bandwidth exchanges, and proposed to use a non-transparent approximation algorithm, because the non-transparence would eliminate the risk of strategic behavior on the part of the bidders.

Daniel Lehmann discussed combinatorial auctions with decreasing marginal utilities, and the consequences of certain bid languages, like OR of single valuations, XOR of single valuations, and OXS: a combination of the two. Interesting here is that winner determination is polynomial-time in the case of OXS bids.

5. STRATEGIES AND BIDDING

Peter Esö presented precautionary bidding strategies in auctions. He argued that risk-averse buyers prefer auctions for riskier[2] items, since the winner's curse actually

[1] Here large means that the number of bids is large with respect to the number of goods.
[2] Here riskier means that there is more noise obscuring the real value of the item to the bidders.

causes prices to decrease.

Makoto Yokoo discussed the effect of false-name bidding on auction protocols and showed that the generalized Vickrey auction protocol is manipulable using false-name bids, that no auction protocol exists that is strategy-proof (i.e. truth-revelation is optimal), Pareto efficient, and individual rational, if players can submit false-name bids. On the other hand, they developed a double auction protocol which combines strategy-proofness (against false-name bids) and individual rationality as long as it is not repeated.

6. ASCENDING PRICE COMBINATORIAL AUCTIONS

Aleksander Pekeč discussed multiround combinatorial auctions, which will be applied in the 700Mhz FCC auction some time after September 2001.

Lyle Ungar presented their software package iBundle, which iterates combinatorial auctions and has as a goal obtaining competitive equilibria.

Sushil Bikhchandani presented their paper on ascending auctions and argued that if items in heterogeneous auctions are not gross substitutes, no ascending auctions will be good, i.e. incentive compatible.

Sven De Vries argued that a common element of known auctions with polynomial-time winner determination in auctions is their matroidal structure. Using the example of minimum spanning tree, he demonstrated how specific ascending price auctions compute Vickrey payments.

7. CONCLUSIONS

This workshop on electronic market design brought together leading researchers from artificial intelligence, economics, game theory, and operations research working on (combinatorial) auctions. Researchers from each field found it very inspiring to discuss together the different approaches taken. The workshop achieved its goal to bring research approaches together which have a great potential to provide the foundation for a theory of electronic markets. Viewing it from an application perspective, there remains a large need to bridge between quite general principles, like those in the package assignment model by Bikhchandani *et al.*, and the design of markets for very specific applications. The economic presentations demonstrated that electronic markets should always be seen in the economic and social context for which they are created, and not just as an engineering exercise.