DIMACS Center
Rutgers University

Special Focus on Computation and the Socio-Economic Sciences

Annual Report

December 2005

Ia. Participants from the program

Participants:

PI: Fred Roberts

Co-chairs:

Lance Fortnow, CS, University of Chicago
Fred Roberts, DIMACS/Rutgers University
Rakesh Vohra, Kellogg School of Management

Organizing Committee:

Joan Feigenbaum, Yale University
Jayant Kalagnanam, IBM Watson Labs
Eric Maskin, School of Social Science, Institute for Advanced Study
Christos Papadimitriou, University of California, Berkeley
Aleksandar Pekec, Duke University
David Pennock, Yahoo!Research
Michael Rothkopf, Rutgers University
Michael Trick, Carnegie Mellon University
Vijay Vazirani, Georgia Tech

Visitors:

Vahab Mirrokni, MIT, 9/1/04-10/1/04
Nicole Immorlica, MIT, 12/19/04-12/24/04
Stefan Wolfgang Pickl, Universitat zu Koln, 5/8/04-5/20/04

DIMACS Workshop on Large-Scale Games
Dates: April 17 - 19, 2005
Location: Evanston Campus, Northwestern University, Evanston, Illinois

Organizers:

Lance Fortnow, University of Chicago
Rakesh Vohra, Northwestern University

DIMACS Workshop on Yield Management and Dynamic Pricing
Dates: August 3 - 5, 2005
Location: DIMACS Center, CoRE Building, Rutgers University

Organizers:

James Dana, Kellogg School of Management, Northwestern
Brenda Dietrich, IBM Watson Labs

DIMACS Workshop on Economic Epidemiology
Dates: October 24 - 25, 2005
Location: DIMACS Center, CoRE Building, Rutgers University

Organizers:

Dave Smith, NIH
Ramanan Laxminarayan, Resources for the Future

Ib. Participating Organizations

Telcordia Technologies: Collaborative Research
Partner organization of DIMACS. Individuals from the organization participated in the program planning.

AT&T Labs - Research: Collaborative Research
Partner organization of DIMACS. Individuals from the organization participated in the program planning.

NEC Laboratories America: Collaborative Research
Partner organization of DIMACS. Individuals from the organization participated in the program planning.

Lucent Technologies, Bell Labs: Collaborative Research
Partner organization of DIMACS. Individuals from the organization participated in the program planning.

Princeton University: Collaborative Research
Partner organization of DIMACS. Individuals from the organization participated in the program planning.

Avaya Labs: Collaborative Research
Partner organization of DIMACS. Individuals from the organization participated in the program planning.

HP Labs: Collaborative Research
Partner organization of DIMACS. Individuals from the organization participated in the program planning.

IBM Research: Collaborative Research
Partner organization of DIMACS. Individuals from the organization participated in the program planning.

Microsoft Research: Collaborative Research
Partner organization of DIMACS. Individuals from the organization participated in the program planning.

Stevens Institute of Technology: Collaborative Research
Partner organization of DIMACS. Individuals from the organization participated in the program planning.

Georgia Institute of Technology: Collaborative Research
Partner organization of DIMACS. Individuals from the organization participated in the program planning.

Rensselaer Polytechnic Institute: Collaborative Research
Partner organization of DIMACS. Individuals from the organization participated in the program planning.

Newsfutures: Collaborative Research
Support of Workshop on Markets as Predictive Devices (Information Markets).

Yahoo! Research Labs: Collaborative Research
Support of Workshop on Markets as Predictive Devices (Information Markets).

Northwestern University: Collaborative Research
Support of DIMACS Workshop on Large-Scale Games.

1c. Other Collaborators

The project involved scientists from numerous institutions in numerous countries. The resulting collaborations also involved individuals from many institutions in many countries.

II. Project Activities

Partnerships between mathematicians and social scientists have existed for a long time, but partnerships between computer scientists and social scientists are relatively new. In the past five years, they have begun to sprout and several important new fields of research are already thriving as a result. The topic of game theory and mechanism design has involved many leading computer scientists with economists and, as a result, for the first time many computer scientists are taking serious note of both the problems and the methods of economics. Analysis of the analogies between the growth of social networks and the development of the Internet have led to important insights about both areas and serious interactions between computer scientists and sociologists. Problems of metasearch have engaged computer scientists with political scientists and economists working on voting and social choice. The objective of the Special Focus on Computation and the Socio-Economic Sciences is to build on these early and exciting connections.

Partnerships between computer scientists and biologists are somewhat of a model for what we are doing. These partnerships have flourished in the past 15 years. They have played a critical

role in the human genome project, have led to a major emphasis on information processing in the biological organism, have spawned intriguing new areas of research in computer science such as DNA computing, and have contributed to major developments in tree reconstruction and pattern matching algorithms in computer science. In short, they have had a profound effect on both biology and computer science. There may not be a specific "big science" challenge such as the human genome project in the case of computer science and the social sciences, but the opportunities for real and significant progress both in the computing and social sciences as a result of new interdisciplinary partnerships are upon us. In fact, the interaction between computer science and the social sciences is changing in dramatic ways that can be expected to have lasting impacts on both disciplines. Many applications in computer science and information technology (IT) involve issues and problems that social scientists (economists, political scientists, sociologists, psychologists and others) have addressed for years, issues of preference, utility, decision making, conflict and cooperation, incentives, auctions, bidding, consensus, social choice, and measurement; and the methods social scientists have developed for dealing with these issues and problems form an impressive toolkit. At the same time, with the widespread availability of today's powerful computers and new and exciting data sets, work in economics, political science, sociology and psychology that was only a theoretical possibility a few years ago is becoming a reality. Applying methods of social science to CS/IT problems requires new computational tools and the development of new variants of these methods. Applying computational methods to the solution of modern social science problems requires the development of new data structures, algorithms, and other tools that are in the domain of the computer scientist.

We have begun to see the use of methods developed by social scientists in a variety of IT applications. The requirements associated with these applications place great strain on the social science methods because of the sheer size of the problems addressed, issues involving computational power of agents, limitations on information possessed by players, and the sequential nature of repeated applications. Hence, there is a great need to develop a new generation of methods to satisfy these CS/IT requirements. In turn, these new methods will provide powerful new tools for social scientists. At the same time, great progress is being made on the problems traditionally of interest to social scientists through the use of new methods for finding patterns in data, searching through databases, computing solutions, and testing models. This Special Focus seeks to develop the new "social-science-based" CS methodologies and to investigate their application to problems of information technology and to problems of the social sciences of fundamental importance to modern society. It also seeks to investigate computer science tools that are especially relevant to emerging problems of the socio-economic sciences. Research into issues of the type we envision requires new interdisciplinary partnerships among computer scientists, mathematicians, operations researchers, economists, experts in business applications, political scientists, psychologists, sociologists, and researchers specializing in the handling of information. Several major research themes span the Special Focus. They include:

- **Computational Tractability/Intractability**. Limits on what can be efficiently computed are very important in social-science-based CS applications and applications of CS methods to the social sciences.
    - Can our understanding of computational complexity help us to build computational tools that will enlarge the set of social science models that can be

analyzed and to adapt social-scientific concepts to solve problems of information technology?
    - How can we characterize situations where intractability is a good thing, as for example when we use it to protect privacy or make it difficult to manipulate the outcome of an election?
- **Limitations on Computational Power/Information**. Increasingly, economic decisions have to be made in situations where there are many "actors" each having partial information or where there are limits to computation that prevent actors from obtaining needed information. Limitations include:
    - informational asymmetries
    - computational limits to extracting information that is available (perhaps in large data sets)
    - cognitive limitations on the part of agents.
- **The Impact on New Methodologies of the Sheer Size of CS/IT Applications**. The sheer size of CS/IT applications requires new methods/protocols where efficiency is a central focus and where issues of scalability and robustness with respect to errors in data are prominent.
- **Learning through Repetition**. Issues of learning, taking advantage of repeated games or auctions or through combining repeated inputs, arise in CS/IT applications in fascinating ways. Some tasks may be delegated to software agents and one needs to understand how they should be designed to "learn" user preferences and how to bid and trade.
- **Security, Privacy, Cryptography**. The need for secure communication and privacy sparks the need for cryptographic methods in the analysis and design of voting procedures, games, and decision processes. Such issues arise in areas like electronic commerce and electronic voting, and many are being discussed in detail in a parallel special focus program on "Communication Security and Information Privacy" at DIMACS. (For more detail about that program, and in particular a list of planned workshops and working groups, see http://dimacs.rutgers.edu/SpecialYears/2003_CSIP/.)
- **Game-theoretic Solution Concepts**. As we consider larger and larger games in modern economic applications, Nash equilibria, solution concepts in cooperative games, and other game-theoretic solution concepts applied in a variety of settings become harder and harder to compute.
- **Markets as Information Sources**. Increasingly individuals and firms are using markets to learn about their competitors' preferences and to aggregate and combine information, for example through the generation of prices. These developments can benefit from methods of distributed computing and combinatorial exchange.
- **Implementation of Auctions**. While dramatic changes in availability of information technology have allowed us to expedite increasingly complex business transactions, for example complex auctions, the ability to implement such transactions often puts a strain on existing computational methods.
- **Designing Markets**. How do we design markets for the exchange of complicated assets like spectrum, stock portfolios, landing rights, and airline routes? The problems involved are different from those of traditional auctions, as there are multiple owners whose assets interact in complex ways.
- **Dynamic Markets**. Ever-more-powerful computers make it increasingly possible to develop sophisticated algorithms that allow actors to adjust prices, bandwidth, etc. in a

dynamic way, as well as adjust schedules and allocations in response to changing market conditions or unforeseen events.

- **Computing Utilities**. Utility functions, which have been studied for a long time by economists and psychologists, are increasingly important in considerations of interest to computer scientists. For both groups, there is the need to compute utilities in larger and larger environments and under conditions of distributed information. These call for new models, tools, and algorithms such as the use of polyhedral combinatorial methods, which are so central to computer science.

The tutorials, workshops, and working group meetings that have been held during the second year of this project are as follows:

DIMACS Workshop on Large-Scale Games
Dates: April 17 - 19, 2005
Location: Evanston Campus, Northwestern University, Evanston, Illinois
Organizers:
Lance Fortnow, University of Chicago
Rakesh Vohra, Northwestern University
Attendance: 25

On the Internet we have games with a large number of agents, asynchronous play, and an absence of full knowledge about the number of agents one is playing against or the beliefs they possess. The Internet is not the only institution to possess these features nor the first. Markets for traditional goods and services as well as travel networks all possess these features.

This workshop was devoted to the analysis of large scale games of the kinds inspired by the Internet and other computer networks, markets, traffic networks and other large systems. We invited papers that showed how to adapt and extend classical game theoretic models to deal with a large number of players, accommodate the absence of common knowledge, common priors, asynchrony in play and distributed computation.

Examples of the kind of work that was discussed in this workshop include price of anarchy models, robust and on-line mechanism design, timing games, asymptotic analysis of traditional auctions, continuous double auctions (two-sided markets) and network formation.

This workshop consisted of 5 invited overview talks (hour long) and a collection of submitted talks (half hour). The overview talks are listed below.

The workshop took place at Northwestern University's Evanston Campus.

OVERVIEW TALKS:

- Network and Coalition Formation: Matthew Jackson, California Institute of Technology
- Price of Anarchy Models: Tim Roughgarden, Stanford University
- Equilibrium Notions for Games with Many Players: Ehud Kalai, Northwestern University
- Mechanism Design Models without the Common Prior: Jason Hartline, Microsoft Research

- Asymptotic Analysis of Market Mechanisms: Mark Satterthwaite, Northwestern University

DIMACS Workshop on Yield Management and Dynamic Pricing
Dates: August 3 - 5, 2005
Location: DIMACS Center, CoRE Building, Rutgers University
Organizers:
James Dana, Kellogg School of Management, Northwestern
Brenda Dietrich, IBM Watson Labs
Attendance: 38

Airlines have routinely used current and historical demand to update their prices and their allocation of seat inventory to different fare classes. This process involves extensive computation, including demand forecasting, modeling of customer behavior, and optimization. Similar problems arise in the pricing of other resource-intensive, time-definite services, such as allocation of bandwidth in telecommunications. Other industries have begun to explore analogous methods for pricing and allocating products and services. Software firms provide decision support tools that aid in determining retail markdowns (when and by how much to mark down merchandise) and category pricing (if you manage a range of close substitutes how do you set prices on each). Integrated into the underlying mathematics are models of buyer behavior. Some of these models assume myopic buyers who make a buy/no-buy decision based on price, and do not consider the option of waiting for a price cut. There is a sizable literature in economic theory that considers pricing in an environment where buyers are forward-looking; however, these models have not been applied to support commercial decision making and this workshop considered them as well as the corresponding challenges for computer science. Major challenges here lie not in code but in the need for new algorithmic ideas that will allow the use of more sophisticated models of buyer behavior.

Until recently yield-management by airlines was done by individual flights or legs, with limited representation of substitutability. Recently, origin-destination methods, which consider multiple routes between the same pair of cities, have been made available by PROS. Capturing these substitution effects required significant, domain-specific modeling, additional input data about schedules and customer preference, and increased computation. Analogous substitution and bundling occurs in other industries such as retail, telecomunication, other travel and transport, but our understanding of customer preference is very limited. In telecomunications or package transport, this may not matter as the customer cares only that the call is completed or the item is transported, not about the specific route that it follows. However, in retail, travel, healthcare, and other services where the composition of the offering is visible to the end customer, a far better understanding of customer preferences is needed. Modeling of bundling and substitution requires an understanding of the physical items and processes under consideration. Incorporating preference for specific items and/or combinations requires an understanding of customer behavior. Methods for systematically using vast amounts of transaction data from sources such as web-sites, point-of sale-terminal, customer surveys, and the like, to build models of customer behavior, remains a significant computational challenge, and one this workshop investigated. A

related issue is the robustness of assumptions about the distribution of demand. This is a natural environment for on-line analysis, again an area of considerable interest to computer scientists.

DIMACS Workshop on Economic Epidemiology
Dates: October 24 - 25, 2005
Location: DIMACS Center, CoRE Building, Rutgers University
Organizers:
Dave Smith, NIH
Ramanan Laxminarayan, Resources for the Future
Attendance: 39

The emergence and spread of resistance to antimicrobial agents is a complex interplay among economics, human behavior, and disease ecology. Mathematical models can help make sense of the complexity and vastly improve our understanding of the interplay among these factors. The DIMACS workshop on economic epidemiology was the first of what we hope will be a series of consultations among economists, computer scientists, mathematicians, and biologists working on issues of infectious diseases modeling and policy. It was jointly sponsored by the DIMACS Special Focus on Computational and Mathematical Epidemiology. A special focus of this first workshop was the management of antimicrobial resistance. Economic incentives play an important role in determining antibiotic use, infection control and the evolution of resistance. At first glance, one notes that those who use or prescribe antibiotics have few or no incentives to consider the impact of their decisions on the rest of society. On further reflection, it is evident that this problem of missing incentives extends to institutions such as hospitals and the pharmaceutical industry. Hospitals operating in the vicinity of many other medical care institutions that share patients may have fewer incentives to invest in hospital infection control to manage resistance if the benefits of their actions mainly accrue to other institutions. Drug firms that are involved in the manufacture of antibiotics similarly may fail to consider the impact of their aggressive antibiotic marketing campaigns on cross-resistance with other antibiotics that are being used. Understanding the role of incentives in the evolution of drug resistance, and the implications for the management of resistance formed the agenda of the first workshop. The broad purpose of the workshop was to encourage greater application of economic intuition and analytical methods to mathematical models of disease evolution.

Mathematical models in epidemiology have provided useful insights into the pathology and virology of different infectious agents. Traditionally, epidemiologists and disease ecologists have modeled the spread of disease without giving much thought to human or institutional behavior. In economics, the focus has been on understanding behavior and incentives of individuals and institutions in the context of infectious diseases; but economists often develop static models, without much regard for disease dynamics. Economic epidemiology (or alternatively, the bioeconomics of infectious disease) uses mathematical models to explore important feedbacks between the spread of infectious diseases and their underlying economic causes as well as the biological ones. These two fields have rarely overlapped despite obvious synergies. This workshop brought together eminent members from each field, identified ways in which the two fields overlap, and expanded thinking on both sides to better understand how diseases emerge, persist and spread over time and space.

III. Project Findings

AdWords and Generalized On-line Matching

How does a search engine company such as Google determine which ads to display with each query such as to maximize Google's revenue? Two special focus participants, Amin Saberi, Microsoft Research, and Vijay V. Vazirani, Georgia Tech, together with Georgia Tech graduate student Aranyak Mehta and Berkeley faculty member Umesh V. Vazirani, addressed this question. Instead of flooding consumers with unwanted ads, Internet search engine companies use what Google calls Adwords that reveal a customer's interests. Ads targeted to those interests are then displayed. The search engine company bills businesses whose ads are displayed and clicked on. Businesses submit bids for individual keywords, together with their maximum daily budget. An algorithm is needed to rank the ads for each query so that the advertisers spend the greatest amount of their daily budget. Such an on-line algorithm must operate in real time without access to the entire set of queries. Saberi, Vazirani, Mehta, and Vazirani realized that the solution to this problem is a generalization of the online bipartite matching problem. They developed two algorithms, one deterministic and one randomized, achieving competitive ratios of $1 - 1/\varepsilon$. The competitive ratio is the worst case of the ratio between the revenue generated by the on-line algorithm and the best-case revenue. Both algorithms are simple and time efficient and Saberi, Vazirani, Mehta, and Vazirani showed that no randomized algorithm can achieve a better competitive ratio.

The researchers have described several future research directions. One direction is how an algorithm might use historical data about a search engine company's queries. Another question is whether it is possible to achieve a competitive ratio of $1 - 1/\varepsilon$ when the budgets of advertisers are not necessarily large relative to the individual bids, as the current algorithms assume. Third, the researchers suggest that their algorithms provide some resilience against gaming schemes and there are several issues in this area that can be explored.

This work has received attention in the general science press. It was described in an article by Sara Robinson in SIAM News, Volume 38, Number 3, April 2005, entitled "Computer Scientists Optimize Innovative Ad Auciton." The article "Google's Thriving Advertising Model Has Math Roots" was posted on PhysOrg.com on May 23, 2005 by Georgia Institute of Technology. We describe in the section on contributions to resources for research and education how this paper has already become part of graduate courses in computer science in major departments in the United States.

Tight Approximation Algorithms for Maximum General Assignment Problems, with Applications to Budget-Constrained Combinatorial Auctions and the AdWords Assignment Problem

Lisa Fleisher, IBM Watson Research Center, Michel Goemans, MIT, Vahab Mirrokni, special focus visitor, and Maxim Sviridenko, IBM Watson Research Center collaborated on a general

class of maximizing assignment problems with packing constraints called SAP problems. A separable assignment problem (SAP) is defined by a set of bins and a set of items to pack in each bin, the value of assigning item j to bin I, and for each bin a set of items that fit in that bin. The goal is to pack items into bins to maximize the total value. This general class of problems includes the maximum generalized assignment problem (GAP), with applications in inventory planning, and a distributed caching problem (DCP). All of these problems are NP-complete since for all of them, the knapsack problem is a special case. Fleisher, Goemans, Mirrokni, and Sviridenko developed an LP-based algorithm and a local search algorithm with an approximation guarantee for all examples of SAP that admit an approximation scheme for the single-bin problem. For cases in which the subproblem admits a fully polynomial approximation scheme, such as GAP, they strengthened the LP-based algorithm. They also extended the approximation algorithm to a nonseparable assignment problem with applications in maximizing revenue for budget-constrained combinatorial auctions and the AdWords assignment problem. They generalized the local search algorithm to yield an approximation algorithm for the k-median problem with hard capacities.

Frugality and Budget Constraints in Truthful Mechanism Design

Consider a situation where there is a set of agents and a client needs to hire a subset of them (a team) to perform a particular task. Certain subsets of agents are designated as feasible; a feasible subset is one that is adequate for the client's needs. Each agent has his own minimum price (known to him) and is supposed to tell this to the client. The client then chooses the team. The obvious selection method is for the client to choose the cheapest feasible set and to pay them each their bid; but this method has the disadvantage that it may provide an incentive for agents to overstate their minimum price. To avoid this, one seeks a truthful mechanism, one that provides no incentive for agents to overstate their price. The drawback to truthful mechanisms is that they typically require the client to incur a higher total cost than might be incurred with a non-truthful mechanism. Karlin et al. introduced a parameter called the frugality ratio that provides a means of quantifying the potential excess cost incurred by the client due to using a particular truthful mechanism. Karlin et al. proposed a truthful mechanism whose frugality ratio is within a constant factor of the optimal for a special class of set systems called an r-out-of-k system. Rutgers University mathematics graduate student Lan Yu and her faculty advisor, Michael Saks proved that the proposed mechanism achieves the optimal frugality ratio for a 1-out-of-k system and thus improved the constant factor by 2 for the analysis of a mechanism for the path auction also presented by Karlin, et al. They are aiming at a more generalized result, a truthful mechanism whose frugality ratio is within a constant factor of the optimal for a wider class of set systems, hopefully all monopoly-free set systems.

They also worked on auctions in the presence of budget constraints. Borgs et al. recently showed the impossibility of truthful auctions in a setting where there are a limited number of copies of a particular good for sale, and each user has a linear utility for copies of the good and a budget constraint. However, their impossibility result assumes that the mechanism is always required to sell all of the units of the good. If this constraint is relaxed, then truthful mechanisms are possible, and Yu and Saks have made progress on the problem of constructing families of truthful auctions in this setting.

Bounding Multivariate Probability Distribution Functions

Suppose we are given d populations from which a sample is to be drawn. This sample will be a d-tuple of units, one from each population. We are also given a probability distribution for each population that specifies the probability of selection and a cost for each possible sample. Given these inputs, we want to find an assignment of joint probabilities to the samples such that these joint probabilities are consistent with the individual probability distributions for each population, and at the same time the expected cost of a sample is minimized. This problem arises in the integration of surveys and in controlled selection. It has extensive applications in the socio-economic literature. Rutgers graduate student Xiaoling Hou and Rutgers faculty member Andras Prekopa studied variants of this problem. They considered multivariate probability distributions with given marginals, along with linear functionals, to be minimized or maximized, acting on them. The functionals were supposed to satisfy the Monge or inverse Monge or some higher order convexity property and they may be only partially known. (An m x n 2-dimensional array (c_{ij}) satisfies the Monge property if $c_{ij} + c_{rs} \le c_{is} + c_{rj}$ for all $1 \le i < r \le m$ and $1 \le j < s \le n$. If $c_{ij} + c_{rs} \ge c_{is} + c_{rj}$ it is called the inverse Monge property. Monge and inverse Monge arrays come up in many practical applications.) Hou and Prekopa reformulated and extended existing results in connection with Monge arrays in terms of LP dual feasible bases. They found lower and upper bounds for the optimum value of the linear functionals satisfying the Monge or inverse Monge properties as well as for unknown coefficients of the objective function based on the knowledge of some dual feasible basis and corresponding objective function coefficients. In the two- and three-dimensional cases, they obtained dual feasible bases for the problem, where not only the univariate marginals, but also the covariances of the pairs of random variables are known.

Anticipating the Stability of Long Term Forecasts

The stability of long-term forecasts is an issue in research on the applications of technology as well as in research questions in various economic applications. There is a tradeoff between the bounded time horizon in which measurements and experiments are made and the much longer term over which processes take place. Tanil Ergenc, Institute of Applied Mathematics, Middle East Technical University, Stefan Pickl, special focus visitor, Nicole Radde, Department of Mathematics and Center of Applied Computer Science, University of Cologne, and Gerhard Weber, Institute of Applied Mathematics, Middle East Technical University collaborated on a research project to utilize generalized semi-infinite optimization to understand and characterize the behavior of dynamic optimization models in terms of their stability and anticipation analysis. They studied the analytical and inverse (intrinsic) behavior of generalized semi-infinite optimization problems and interpreted them from the viewpoint of anticipatory systems. Under suitable assumptions, they established global stability properties of the feasible set and corresponding structural stability properties of the entire optimization problem.

IV. Project Training/Development

One of the major objectives of the special focus is to provide opportunities for junior researchers to develop interdisciplinary collaborations early in their careers. Even this early in the project, we are already getting indications that the special focus is being successful in this regard. Here are some comments from participants:

"The program allowed me to meet people of my research field and to develop new research ideas in connection with what I've done so far in my Ph.D. thesis. I will probably communicate my research project to some of the people that were present at the workshop in order to know their feedback." Markus Herrmann, Université de Montréal

"A belated thank you for organizing last month's Information Markets workshop. It's helping me immensely with writing my thesis for a Master's in Public Administration!" Mary Kate Preziosi, AT&T Research

We also supported several graduate students for small research projects under this grant.

Xiaoling Hou, RUTCOR, Rutgers University
"Bounding multivariate probability distribution functions"

Tongyin Liu, RUTCOR, Rutgers University
"Stochastic programming problems with poisson and binomial distributions"

Amit Agarwal, CS, Princeton University
"Bounding the 'price of stability' for undirected networks"

Adriana Karagiozova, CS, Princeton University
"Online algorithms for buy-at-bulk network design"

Lan Yu, Mathematics, Rutgers University
"Frugality of truthful mechanisms"

V. Outreach Activities

VI. Papers/Books/Internet

Papers

Ergenc, T. , Pickl, S., Radde, N. and Weber, G.-W., "Generalized semi-infinite optimization and anticipatory systems" *International Journal of Computing Anticipatory Systems*, **15** (2005), 3-30.

Hajiaghayi, M., Kortsarz, G., Mirrokni, V. and Nutov, Z., "Power optimization for connectivity problems," *Integer Programming & Combinatorial Optimization* (IPCO), (2005), to appear.

Hou, X., and Prekopa, A., "Monge property and bounding multivariate probability distribution functions with given marginals and covariances," submitted.

Hou, X., and Prekopa, A., "Monge property and bounding multivariate probability distribution functions with given marginals and covariances," DIMACS TR: 2005-34, (2005).

Hou, X., and Prekopa, A., "Monge property and bounding multivariate probability distribution functions with given marginals and covariances," RUTCOR Research Report RRR 27-2005, (2005).

Mehta, A., Saberi, A., Vazirani, U.V. and Vazirani, V.V., "AdWords and generalized on-line matching," *Proceedings of the 46th Annual IEEE Symposium on Foundations of Computer Science* (FOCS 2005), Pittsburgh, PA, (2005).

Mirrokni, V.S., Fleischer, L., Goemans, M. and Sviridenko, M., "(Almost) Tight approximation algorithms for maximizing general assignment problems," *SODA*, (2006).

Saks, M., and Yu, L. "Weak monotonicity suffices for truthfulness on convex domains," *Proceedings of the 6th ACM Conference on Electronic Commerce*, Vancouver, Canada (2005), 286-293. (An expanded version of this paper is in preparation for journal submission.)

Books

Talks

Hartline, J., "Optimal mechanism design without priors," The Sixth ACM Conference On Electronic Commerce, June 5, 2005.

Hou, X., "Monge property and bounding multivariate probability distribution functions with given marginals and covariances," Third Rutgers-Stevens Workshop on Risk-Averse Optimization, Rutgers University, October 1, 2005.

Lozovanu, D. and Pickl, S., "Algorithmic solutions for discrete optimal control problems on networks and its game-theoretic extension," Cologne Twente Workshop CTW2005 on Graphs and Combinatorial Optimization, Cologne, May, 2005.

Mehta, A., Saberi, A., Vazirani, U.V. and Vazirani, V.V., "AdWords and generalized on-line matching," 46th Annual IEEE Symposium on Foundations of Computer Science (FOCS 2005), Pittsburgh, PA, October 23-25, 2005.

Mirrokni, V., "New algorithms and mechanisms for assignment problems," IBM Alamadan Research Center, January 20, 2005.

Mirrokni, V.S., "Power optimization for connectivity problems," INFORMS Annual Meeting, San Francisco, November 13, 2005.

Saberi, A., "AdWords and generalized on-line matching," INFORMS Annual Meeting, San Francisco, November 14, 2005.

Yu, L., "Weak monotonicity suffices for truthfulness on convex domains," 6th ACM Conference on Electronic Commerce, Vancouver, Canada, June 5, 2005.

Internet

Main web site for the Special Focus on Computation and the Socio-Economic Sciences
http://dimacs.rutgers.edu/SpecialYears/2004_CSEC/

VII. Other Products

Main web site for the DIMACS Workshop on Large-Scale Games
http://dimacs.rutgers.edu/Workshops/Games/

Main web site for the DIMACS Workshop on Yield Management and Dynamic Pricing
http://dimacs.rutgers.edu/Workshops/Yield/

Main web site for the DIMACS Workshop on Economic Epidemiology
http://dimacs.rutgers.edu/Workshops/EconEpid

Yahoo Group on Information Markets
http://groups.yahoo.com/group/marketstructure

VIII. Contributions within Discipline

The special focus is by nature both multidisciplinary and interdisciplinary. We mention some of the important interdisciplinary accomplishments in the section on Contributions – Other Disciplines. Several collaborations between individuals within the same discipline have already resulted from the special focus. Here are two examples:

Nicole Immorlica, MIT, was a special focus visitor during the first year of this project and reports that she worked on problems related to computational economics. She focused on two particular problems: maximizing the minimum fairness and designing welfare-maximizing auctions for bidders with submodular utility functions. She collaborated with Lisa Fleischer, Tracy Kimbrel, Maxim Sviridenko, and Baruch Schieber, all IBM Watson employees. She also met William Walsh for the first time and intends to continue collaborations with all of these people.

Vahab Mirrokni, MIT graduate student, was a special focus visitor to IBM T. J. Watson research center for a month in the summer of 2004 and worked on several problems including distributed caching and general assignment problems, and power optimization in wireless networks. While

there he collaborated with Lisa Fleischer, IBM Watson, Maxim Sviridenko, IBM Watson, Baruch Schieber, IBM Watson, and Guy Kortsarz, Rutgers Camden. He also was a participant in the workshop Large Scale Games. The several talks and articles that resulted are listed in the section on articles and talks.

The Workshop 'Markets as predictive devices' really was the first to bring together researchers in this area and has helped grow it dramatically such as this big Stanford event: http://www.kmcluster.com/sfo/PM/PM.htm, which may never have happened if some of the organizers didn't first get together at DIMACS. The event was the Prediction Markets Summit held December 2, 2005 at the UCSF Mission Bay Community Center, sponsored by CommerceNet, NewsFutures, Colabria and KM Cluster, and featuring such business leaders as Google, Yahoo!, Microsoft, Stanford Graduate Business School, HPLabs and others.

IX. Contributions -- other Disciplines

The special focus is by design interdisciplinary. One of the main objectives is to facilitate interactions and collaborations across disciplines by introducing people with common research interests but in different disciplines who may not otherwise have met. Several of these interactions and collaborations have already begun. For example:

"I went to a session 'Dynamic Pricing and Yield Management' which was run and mainly participated in by folks not in my field, who work on problems related to those I work on. It definitely led to my spending a week visiting Northwestern. Some new directions have come out of this visit." Jason Hartline, Microsoft Research

The following sums up very well the interdisciplinary nature of the special focus:

"I think the Epidemiological Economics is a quite new field and the workshop will probably help to form a known discipline, as it was with the Environmental Economics before." Markus Herrmann, Université de Montréal

"The Economic Epidemiology meeting at DIMACS on Oct 23-24 generated a healthy dialogue. In the discussion, we identified areas of overlap between these areas as well as economic and epidemiologic papers that could have been improved if they had been combined effectively. Collaborations between individuals of different disciplines have been facilitated by the workshop and will likely continue, and we are in the process of fostering an area of study and a community in a new academic community." Ramanan Laxminarayan, Resources for the Future, and David Smith, NIH

"The workshop on economic epidemiology, or as we are beginning to call it, the bioeconomics of infectious disease, was the inaugural meeting of a new multi-disciplinary academic community. Ram and I will continue to work on projects that began before the conference -- the bioeconomics of antimalarial resistance and the bioeconomics of antibiotic resistance in the U.S. The one new manuscript that arose out of this conference (that we know) will be an introduction to define the key issues and activities of this multi-disciplinary endeavor." David Smith, NIH

Here is a comment from a participant in DIMACS Workshop on Markets as Predictive Devices (Information Markets) February 2-4, 2005.

"There is a good deal that our securities industry folk and these Information Market folk can learn from each other, though I'm not sure most of us know it yet." Brooke Allen, MANE Fund Management, Inc.

X. Contributions -- Human Resource Development

Many graduate students have participated in the special focus programs. We set aside funds in each workshop budget for support of students. A partial list of graduate student participants is the following:

DIMACS Workshop on Large-Scale Games

- Varsha Dani, University of Chicago
- Samuel Ieong, Stanford University
- Robert McGrew, Stanford University
- Vahab Mirrokni, MIT
- Evdokia Nikolova, MIT
- Mallesh Pai, Kellogg School of Management

DIMACS Workshop on Yield Management and Dynamic Pricing

- Akshay Reddy Katta, Columbia University
- Yingjie Lan, University of Maryland
- Qian Liu, Columbia University
- Lila Rasekh, McGill University
- Ozge Sahin, Columbia University
- Semih Onur Sezer, Princeton University
- Tomer Yahalom, Stanford University

DIMACS Workshop on Economic Epidemiology

- Markus Herrmann, Université de Montréal
- Baik Hoh, WINLAB/Rutgers University
- Lisa V. Kim, University of Washington
- Omayra Y. Ortega, University of Iowa
- Denise Serrano, Rutgers University
- Derek W. Willis, Princeton University

Here is a comment from a participant indicating how the special focus has influenced both his research program and classroom materials.

"I also gave a survey talk at the workshop on "Large Scale Games". The process of preparing this talk led me to think about problems I've spent a lot of time working on in a very different

light. I'm actively exploring new research questions as a result of this different viewpoint. I also, extended my survey talk into a 3 hour long tutorial at the Electronic Commerce conference and then into a third of a course that I'm currently teaching at Stanford (in the Computer Science Dept). Jason Hartline, Microsoft Research

There was synergy between this project and the DIMACS collaboration with the Laboratory for Analyzing and Modeling Decision-Aid Systems (LAMSADE) at University of Paris IX, supported by a different NSF grant. The LAMSADE collaboration deals with computer science and decision theory.

The impact of the LAMSADE collaboration on Rutgers graduate students Tiberius Bonates and Marcin Kaminski is expressed in their own words:

"The LAMSADE [collaboration] was remarkably beneficial to me, as it opened my view to different topics of study, broadening the horizons of my research, and as it introduced me to competent researchers with whom I plan to continue collaborating in the future."
Tiberius Bonates

"I find my [collaboration with] LAMSADE very successful. Working with researchers at LAMSADE, I was introduced to algorithmic problems that I had not studied before and together we were able to design new, fast algorithms. There is a lot of room for improvement and I am planning to continue working with them in that field." Marcin Kaminski

XI. Contributions to Resources for Research and Education

The article "AdWords and Generalized On-line Matching" by Aranyak Mehta, Amin Saberi, Umesh V. Vazirani, Vijay V. Vazirani has quickly become a useful resource for graduate level computer science courses throughout the country. Shouxi Yang presented the paper in the Algorithms Reading Group at University of Iowa in Fall 2005. Andrew Schwartz chose this project topic in the Algorithmic Game Theory course at Stanford in Fall 2005. This paper was a reference for a lecture in the Algorithms for Complex Networks course at Georgia Tech in Spring 2005. Danny Goodman and Laura Serban based their presentation for CS286 at Harvard in Spring 2005 on this paper.

One of the outcomes of the DIMACS Workshop on Markets as Predictive Devices (Information Markets) held February 2-4, 2005, during the first year of the project, was the formation of an electronic community to continue the discussion that was started during the workshop among those in the securities industry, academics, and industrial research. This was accomplished using the Yahoo Group: http://groups.yahoo.com/group/marketstructure, creating a new folder, "Information Markets." The industry members of this group are having discussions with the academic and student members, not only to share ideas, but also as a way of finding students to hire and research to sponsor. The administrator has issued 37 digests to date, which are distributed via an email list compiled during the Information Markets workshop. These digests have included such items as a discussion of definitions, links to information market websites

where you can cast opinions, notices of conferences and papers, discussion of patents on information markets, and notices of jobs and internships available to students.

Here is an example of how one participant is using the electronic group in the classroom.

"I am about to tell my 100 students about this group. I have finally taught them about limit orders, market orders, limit order books, cumulative depth, walking up the book, auction markets, and so on, so they are ready to start participating. Of course, only a few will join, but the few that do will be among the most interested, or those with jobs at investment banks or GE Asset Management." D. Goldstein

Brooke Allen, MANE Fund Management, the Market Structure group Administrator, used an information market trading platform as a training and hiring exercise. Here is a description.

"I am trying to apply 'Information Market' principles to the hiring of our next two employees. We ran an ad and after an initial screen gathered about 25 candidates into a group at a meeting where I taught them in most basic terms how markets worked. I then told them that I viewed them as the sell side of a labor market and I was on the buy side. I wanted them to organize themselves into a market using some principles I illustrated and set about finding work for each other. I asked them to grant me the favor of having a right of first refusal.

"Within a day they had created a Yahoo group so they could communicate among themselves: http://finance.groups.yahoo.com/group/candidcandidate." Brooke Allen, MANE Fund Management, Inc.

Stefan Pickl, Institut für Angewandte Systemwissenschaften und Wirtschaftsinformatik, Fakultät für Informatik, Universität der Bundeswehr München, visited Dimacs as part of this special focus during May 2004. One of the outcomes that Pickl reports is the creation of a new multi-institutional project.

"I founded the project EXPO (Experimental Process Optimization) between the Karl-Franzens-University in Austria and the University of Heidelberg (Germany) and the University of the Federal Armed Forces Munich. A first workshop with the title "Challenges in the Optimization of Biosystems Auctioning and Emission Trading Markets" will take place in May 2006 in Graz, Austria. Invited speakers are Prof. Klaus Lackner (The Earth Institute at Columbia University New York) "Sustainable Growth and Market Behavior" and Dr. Hans Georg Zimmermann (Siemens, Munich) about the Forecasting of New Energy Markets." Stefan Pickl, Institut für Angewandte Systemwissenschaften und Wirtschaftsinformatik, Fakultät für Informatik, Universität der Bundeswehr München

XII. Contributions Beyond Science and Engineering

Google and other search engine Internet companies are becoming an increasingly important part of daily life. It benefits the users as well as the internet companies when these search engines use algorithms that serve to provide a user with useful information. It is for this reason that Internet search engine companies use what Google calls Adwords that reveal what information a

customer wants instead of flooding consumers with unwanted ads. The work of two special focus participants, Amin Saberi, Microsoft Research, and Vijay V. Vazirani, Georgia Tech, together with Georgia Tech graduate student Aranyak Mehta and Berkeley faculty member Umesh V. Vazirani, contributes to the efficient functioning of internet search engines.