DIMACS Center
Rutgers University

Special Focus on Computation and the Socio-Economic Sciences

Annual Report

December 2006

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:

Navin Goyal, McGill University, 7/10/06-7/17/06

DIMACS Workshop on Polyhedral Combinatorics of Random Utility
Dates: May 24 - 26, 2006
Location: DIMACS Center, CoRE Building, Rutgers University

Organizers:

Jean-Paul Doignon, Univ. Libre de Bruxelles
Aleksandar Pekec, Fuqua School of Business, Duke University

DIMACS Workshop on Information Security Economics
Dates: January 18 - 19, 2007
Location: DIMACS Center, CoRE Building, Rutgers University

Organizers:

Alessandro Acquisti, Carnegie Mellon University
Jean Camp, Indiana University

DIMACS Workshop on Auctions with Transaction Costs
Dates: March 22 - 23, 2007

Location: DIMACS Center, CoRE Building, Rutgers University

Organizers:

Eric Rasmusen, Indiana University
Michael Rothkopf, Rutgers University
Tuomas Sandholm, Carnegie Mellon University

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.

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 interacting 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 something 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 or will have been held during the third year of this project are as follows:

DIMACS Workshop on Polyhedral Combinatorics of Random Utility
Dates: May 24 - 26, 2006
Location: DIMACS Center, CoRE Building, Rutgers University
Organizers:
Jean-Paul Doignon, Univ. Libre de Bruxelles
Aleksandar Pekec, Fuqua School of Business, Duke University
Attendance: 23

Utility functions have a long history in economics and psychology but have recently caught the attention of computer scientists in various applications. Random utility approaches have been extensively used in the social sciences. The fundamental idea is that utilities of agents could be hard or even impossible to precisely assess or elicit, so one should model these utilities as random variables. This modeling approach could turn out to be useful in developing and solving optimization problems and algorithms for which there is no time to or where it is impossible to assess/obtain input data precisely. Such situations could be of interest in computing tasks with massive input data sets as well as tasks in which data corresponds to agent valuations that have to be elicited (such as pricing data like the willingness to buy/pay at a given price). Discrete choice models, i.e., situations in which utilities of only finitely many objects have to be elicited, are of special interest (and have been studied extensively, for example with regard to transportation systems, consumer choice in marketing, etc.) Many discrete choice models have a natural polyhedral representation and these representations have been studied mostly by the mathematical psychology community.

Several interesting discrete choice models give rise to the study of well-known polytopes, with the Binary Choice Polytope as a prominent example. The very same polytope is also well-studied in the operations research community as the feasible set of an optimization problem on rankings. It was therefore dubbed the Linear Ordering Polytope. Other new polytopes such as the Approval Voting Polytope have shown up more recently in studies of random utility models of subset choice and could be of potential interest to the operations research community. In general, the questions of model characterization and of fitting these random utility models to the experimental data are often equivalent to finding complete linear descriptions and optimizing over corresponding polyhedra. On the other hand, it is plausible that some of the well-studied polyhedra in polyhedral combinatorics and combinatorial optimization could be used to design new discrete choice models that could be easily testable.

The three-day workshop allowed the exchange of ideas between researchers in random utility on the one side and polyhedral combinatorics on the other, with inclusion of computer scientists with expertise on algorithmic approaches to such problems as well as computer scientists with an interest in modern applications in IT. The ultimate goal is to define a program and general theory of developing random utility models that can be efficiently characterized and tested through experimental data.

DIMACS Workshop on Information Security Economics
Dates: January 18 - 19, 2007
Location: DIMACS Center, CoRE Building, Rutgers University
Organizers:

Alessandro Acquisti, Carnegie Mellon University
Jean Camp, Indiana University

The deployment of an information security solution can be evaluated on whether the benefits expected from its deployment are higher than the costs of its deployment. Yet it is hard to quantify both benefits and costs, due to uncertainty about factors such as attackers' motivations, probability of an attack, and cost of an attack. This uncertainty about the value of tangible costs and benefits is complicated by intangible costs and benefits, such as user and market perceptions of the value of security. The field of economics has well developed theories and methods for addressing these types of uncertainty. As a result, there has been a growing interest in the economics of information security. Past notable work used the tools of economics to offer insights into computer security, offered mathematical economic models of computer security, detailed potential regulatory solutions to computer security, or clarified the challenges of improving security as implemented in practice. The goal of this workshop is to expand that interest in economics of information security. To meet this goal the workshop will bring together researchers already engaged in this interdisciplinary effort with other researchers in areas such as economics, security, theoretical computer science, and statistics. Topics of interest include economics of identity and identity theft, liability, torts, negligence, other legal incentives, game theoretic models, security in open source and free software, cyber-insurance, disaster recovery, reputation economics, network effects in security and privacy, return on security investment, security risk management, security risk perception both of the firm and the individual, economics of trust, economics of vulnerabilities, economics of malicious code, economics of electronic voting security, and economic perspectives on spam.

DIMACS Workshop on Auctions with Transaction Costs
Dates: March 22 - 23, 2007
Location: DIMACS Center, CoRE Building, Rutgers University
Organizers:
Eric Rasmusen, Indiana University
Michael Rothkopf, Rutgers University
Tuomas Sandholm, Carnegie Mellon University

In the produce auctions held in Vineland, New Jersey, the auctioneer must give the winning bidder the slip of paper the winner needs to claim the lot. He does this by putting the slip into an old tennis ball with a slit in it and throwing the ball to the winner. This saves several seconds per lot for the approximately fifty buyers and fifty waiting farmers. The time needed to select and document the winner of an auction is an example of a transaction cost. Auction theory largely explains a world without transaction costs. This is now changing, and the change is having dramatic effects on auction theory.

First of all, as the introductory example indicates, participating in the auction may be costly. Transaction costs can be a factor in the choice of auction form. For example, the Dutch auctions used in the Dutch wholesale flower markets take less than one fifth of the time of the English auctions used in the Vineland auctions. When we teach auction theory, we often mention this, but it is absent in the models. In addition, continued participation in an auction can have costs that affect bids and choice of auction form.

Secondly, learning his value is not free for a bidder. Indeed, in some cases cost estimating or value estimating is a major undertaking. Some bidders may choose to scrimp on those expenditures and bid cautiously, and others may want the very best estimate they can get. Still others may decline to incur the cost of preparing a bid since the expected profit from participating in the auction is less than the bid preparation cost. Thus, a theory of auctions with transaction costs can be a theory of auction entry. It has recently been shown that, when bid preparation costs vary continuously with the quality of the value estimate, there are no reasonable dominant strategy auctions. Of similar importance is the development of a theory of the use of sniping in hard-close auctions like those on eBay to influence the likelihood that competitors will go to the trouble to prepare an aggressive bid.

Third, bid takers incur costs in preparing documentation on what is to be auctioned, in defining lots, and in deciding whom to qualify as bidders. They must balance the value of getting additional bidders against the cost of qualifying them, and also take account of the possibility that their decision to qualify additional bidders may affect the assumptions and behavior of previously qualified bidders.

Fourth, there are costs of publicizing auctions and gathering bidders. These can affect the timing of auctions and lead to grouping of auctions for similar items. Once several items are being auctioned at approximately the same time, the possibility of using combinatorial auctions arises. This raises many new issues, the least studied of which involve transaction costs. The winner determination problem is NP complete and thus potentially costly to solve. There are important issues related to the bidders' costs of preparing and communicating bids: if bids on all possible combinations are required, as in some auction forms, this cost could grow exponentially with the number of items being auctioned. Sophisticated preference elicitation methods may be needed. Even the cost of transferring ownership rises: it is easier to say that X has won the entire state of California than to record that he has won a particular group of unconnected counties.

Auction theory has been an exciting area of research this past ten years because of the many complications that arise from asymmetric information and the way different auction rules aggregate that information. Auction theories dealing with transaction costs are now being developed, however, and this workshop will bring together researchers working on them. We hope that not only will participants hear each others' ideas, but that their interaction will generate new questions and new insights about which auction forms are superior for which kinds of situations.

III. Project Findings

Epidemiological Implications of Social Structure

Nina Fefferman (DIMACS/Tufts University) and Ramanan Laxminaranyan (Resources for the Future) met and began a collaboration on the epidemiological implications of social organization at the workshop on Economic Epidemiology (October 2005) sponsored under this Special Focus. They have created a series of utility theoretic models to understand how balancing needs for collaborative activity can be achieved, under different scenarios of disease risk, by altering the

social organization of the population. The organization of social groups, especially those involved in the completion of collaborative tasks, necessitates the sort of close contacts that facilitate the transmission of infectious disease. Mitigating such risk via strategic social organization is a non-trivial problem, but it is not unique to human endeavor. It is also crucial in the natural world, especially within colonies of social insects (e.g. ants, wasps, bees, termites). These colonies are under such severe evolutionary pressures that failure to balance these interests can lead to the death of the colony. As a result, it is not unreasonable to suspect that observable patterns of social organization in social insects should approximate the same mathematically determined strategies. Fefferman and Laxminaranyan therefore compare the theoretically derived organizational strategies, based on disease risks, to the social organizations in different populations of social insects.

Complexity and Testing Forecasters

Special Focus co-organizers, Lance Fortnow (University of Chicago) and Rakesh Vohra (Northwestern University), have done research showing how complexity provides insight into issues surrounding the testing of forecasts and model validity. Consider, for example, a weather forecaster predicting the probability of rain for the next day. Given a finite sequence of such forecasts and the subsequent outcomes, the forecaster will either be passed or failed. Earlier work by Sandroni showed that any test which passes a forecaster who knows the distribution of nature, can be probabilistically passed by a forecaster with no knowledge of future events. Fortnow and Vohra identified a linear-time test and a distribution of nature such that any forecaster without knowledge of the future that can fool the test must be able to solve PSPACE-hard problems by requiring the forecaster to simulate a prover in an arbitrary interactive proof system.

Online Portfolio Optimization

Amit Agrawal (Princeton University), recipient of a graduate student research award under this Special Focus, along with several collaborators developed efficient algorithms for portfolio optimization that guarantee logarithmic regret when the loss functions satisfy a mildly restrictive convexity condition. Experimentally their algorithms yield almost the same wealth as the best constantly-rebalanced portfolio with perfect hindsight. These new algorithms are the first to combine optimal logarithmic regret bounds with efficient deterministic computability. They are based on the Newton method for offline optimization, and so unlike previous approaches, they are able to exploit second order information.

Fair Payments and Efficient Allocations in Public Sector Combinatorial Auctions

Special Focus participants Robert Day (University of Connecticut) and S. Raghavan (University of Maryland) considered the problem of fairly pricing public goods in a combinatorial auction. A widely-recognized problem with the Vickrey-Clarke-Groves (VCG) auction mechanism is that the resulting prices may not be in the core, which admits the possibility that the amounts paid by winners could be so low that there would have been others willing to pay more. Such an outcome is unacceptable for a public-sector auction. Day and Raghavan's research addresses critical theoretical and computational issues in the bidder-Pareto-optimal core payment. Seeking to minimize a bidder's ability to benefit through strategic manipulation (such as collusive

agreement or unilateral action), Day and Raghavan demonstrated the strength of a mechanism that minimizes total payments among all such auction outcomes, narrowing the previously broad solution concept. They also addressed computational challenges in achieving these outcomes using a constraint-generation approach.

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. For example, Joachim Giesen (Max-Planck-Institut für Informatik), a recent Ph.D. in computer science, reports that he and Michel Regenwetter (University of Illinois), a mathematical psychologist, met and began collaborating on topics involving repeated game playing at the Workshop on Polyhedral Combinatorics of Random Utility. Giesen reports that new results, joint with his graduate student Evangelia Pyrga, are now in preparation.

Michel Regenwetter (University of Illinois) likewise reports new interdisciplinary collaborations involving his student Clintin Davis-Stober and says "[The workshop] has had an impact on my graduate student's (Davis-Stober) choice of research projects. Clintin Stober-Davis and I have embarked on an intensive collaboration with Samuel Fiorini and Jean-Paul Doignon from Brussels."

We have supported several graduate students for small research projects under this grant. For instance, Amit Agrawal, a graduate student in Computer Science at Princeton University, received an award for summer research under this grant in 2005. The award helped him to pursue research in a variety of areas and has led to several publications that are listed in Section VI. As part of his project "Bounding the Price of Stability for Undirected Networks", Agrawal shows that under fair cost allocation any Nash Equilibrium is worst by a factor O(log n/log log n) in undirected networks for constant edge costs, while under arbitrary cost functions, the price of stability can be O(log n). A paper on these results is in preparation.

In December 2006, we awarded funding to two graduate students for research projects.

Paul Raff, Mathematics, Rutgers University
"The Firefighter Problem in the Two-dimensional Grid"

The firefighter problem is a relatively simplistic model for spread (of disease, fire, rumors, ideologies etc.) through a network or graph. In this problem, some of the vertices in a graph are initially set on fire (or infected). At each turn, the fire (or disease, rumor, ideology) spreads to adjacent vertices but a "player" is able to locate a specified number of "firefighters" to prevent spread through the graph. Raff's work will seek measures for guiding the placement of firefighters in the graph at each turn.

Yang Huang, CS, Rutgers University
"Clustering Temporal Gene Expression Matrices Using Galois Lattice, with Applications to Social Network Structure and Knowledge Diffusion"

In time-series microarray experiments, gene expression data are represented in temporal gene-expression matrices (TGEMs), where rows correspond to genes and columns correspond to time points. Each row represents a time series of expression values of a certain gene. Huang proposes to use Galois lattice to address the problem of class discovery in a set of TGEMs. The immediate goal of the project is to develop a stable and scalable computational tool to cluster gene-expression matrices to help distinguish different disease subtypes. This work may also have broader applicability in the social sciences as the lattice provides an alternative way to study the interaction between the change of social network structure and knowledge diffusion in a society. To build a Galois lattice for the large volume of data that may be contained in a social network an efficient construction algorithm will be required.

V. Outreach Activities

The DIMACS Bio-Math Connect Institute, supported by another NSF grant, brings together biology and mathematics teachers in high schools and introduces them to topics that they can bring into their classrooms. In the summer 2006 BMCI program, teachers were introduced to mathematical modeling of infectious diseases. The social science aspects of disease modeling, which have played a role in this Special Focus on Computation and the Socio-Economic Sciences, were prominently discussed.

Those same social science aspects of disease were also prominently discussed at a DIMACS workshop on mathematical modeling of infectious diseases of Africa, held in South Africa in September 2006 (supported by other grants). The workshop on Economic Epidemiology supported under this Special Focus had great influence on the Africa workshop, by leading us to emphasize economic aspects of allocation of scarce resources for fighting disease in developing countries and other economic/social science aspects of disease modeling. The attendees at the workshop included some 20 US and African students, and the US students came mostly from minority-serving institutions such as Morgan State University, Howard University, and North Carolina A&T.

VI. Papers/Books/Internet

Papers

A. Agarwal, E. Hazan, S. Kale and R. Schapire, “Algorithms for Portfolio Management based on the Newton Method,” in *Proceedings of the 23rd International Conference on Machine Learning* (ICML06), Pittsburgh, PA, June 25-29, (2006).

R. Day and S. Raghavan, “Fair Payments and Efficient Allocations in Public Sector Combinatorial Auctions,” to appear in *Management Science*.

J. P. Doignon, S. Fiorini, F. Glineur, C. Davis-Stober, and M. Regenwetter, “On the Best-Worst Choice Polytope,” in preparation.

J. P. Doignon, S. Fiorini, A. Marley, and R. Suck, "New Approaches to Analysis of Choice Data," in preparation.

L. Fleischer, M.X. Goemans, V.S. Mirrokni, and M. Sviridenko, "Tight Approximation Algorithms for Maximum General Assignment Problems," Proceedings of the 17th ACM-SIAM Symposium on Discrete Algorithms, Miami, Florida, January 22-24, pp. 611-620, (2006).

L. Fortnow and R. Vohra, "The Complexity of Forecast Testing," Electronic Colloquium on Computational Complexity Report TR06-149, 2006.

L. Fortnow and R. Vohra, "The Complexity of Forecast Testing," STOC, submitted.

M. Gargano and M. Kasinadhuni, "Rank Aggregation for Metasearch Engines using a Self-adapting Genetic Algorithm with Multiple Genomic Representations," *Congressus Numerantium*, 176 (2005), pp. 25-31.

B. Grimm, S. Pickl and A. Reed, "Management and Optimization of Environmental Data within Emission Trading Markets, VEREGISTER AND TEMPI," in R.Antes, B. Hansjürgens, P.Letmathe (eds.), *Emissions Trading and Business*, Physica Verlag, pp.165-176, (2006).

M. Hajiaghayi, G. Kortsarz, V. Mirrokni, and Z. Nutov, "Power Optimization for Connectivity Problems." A preliminary version appeared in the *11th Conference on Integer Programming and Combinatorial Optimization* (IPCO), pp. 349-361, Berlin, Germany, June 2005. A finalized version is to appear in a special issue of *Mathematical Programming, Series B* for selected papers from IPCO 2005.

E. Hazan, A. Kalai, S. Kale, and A. Agarwal, "Logarithmic Regret Algorithms for Online Convex Optimization," in *Proceedings of the 19th Annual Conference on Learning Theory* (COLT06), Pittsburgh, PA, June 22-25, (2006).

X. Hou and A. Prekopa, "Monge property and bounding multivariate probability distribution functions with given marginals and covariances," *SIAM Journal on Optimization*, to appear.

D. Lozovanu and S. Pickl, "Nash Equilibria Conditions for Cyclic Games with p Players," in *Electronic Notes in Discrete Mathematics* 25, Elsevier, pp. 123-129, (2006).

D. Lozovanu and S. Pickl, "Algorithms for Solving Multiobjective Discrete Control Problems on Dynamic c-Games on Networks," to appear in *International Journal for Discrete Applied Mathematics*.

D. Lozovanu and S. Pickl, "Algorithms and the Calculation of Nash Equilibria for Multi-Objective Control of Time-Discrete Systems and Polynomial-Time Algorithms for Dynamic c-Games on Networks," to appear in *European Journal of Operational Research*.

Books

Special Issue of Production and Operations Management edited by James Dana & Brenda Dietrich, in preparation, expected publication in 2007.

Talks

A. Agarwal, E. Hazan, S. Kale and R. Schapire, "Algorithms for Portfolio Management based on the Newton Method," *23rd International Conference on Machine Learning* (ICML06), Pittsburgh, PA, June 25-29, 2006.

N. Fefferman, "Preparing Social Infrastructure Against Disease-Related Workforce Depletion," DIMACS Workshop on Facing the Challenge of Infectious Diseases in Africa, Johannesburg, South Africa, September 25-27, 2006.

L. Fleischer, M.X. Goemans, V.S. Mirrokni and M. Sviridenko, "Tight Approximation Algorithms for Maximum General Assignment Problems", 17th ACM-SIAM Symposium on Discrete Algorithms, Miami, Florida, January 22-24, 2006.

E. Hazan, A. Kalai, S. Kale, and A. Agarwal, "Logarithmic Regret Algorithms for Online Convex Optimization," 19th Annual Conference on Learning Theory (COLT06), Pittsburgh, PA, June 22-25, 2006.

R. Laximinarayan, "Insights from Economic Epidemiology," DIMACS Workshop on Facing the Challenge of Infectious Diseases in Africa, Johannesburg, South Africa, September 25-27, 2006.

S.W. Pickl, "Design and Optimization of Emission Trading Markets and Sustainable Bargaining Systems," 21st European Conference on Operational Research (EURO 2006), Reykjavík, Iceland, July 2-5, 2006.

F.S. Roberts, "Social Choice and Computer Science," 21st European Conference on Operational Research (EURO 2006), Reykjavík, Iceland, July 2-5, 2006.

F.S. Roberts, "Computer Science and Decision Making," DIMACS/LAMSADE Workshop on Voting Theory and Preference Modeling, Paris, France, October 25-28, 2006.

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 DIMACS Workshop: Polyhedral Combinatorics of Random Utility
http://dimacs.rutgers.edu/Workshops/RandomUtility/

Main web site for DIMACS Workshop: Information Security Economics

http://dimacs.rutgers.edu/Workshops/InformationSecurity

Main web site for DIMACS Workshop: Auctions with Transaction Costs
http://dimacs.rutgers.edu/Workshops/Auctions/

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.

For example, James Dana (Northwestern University) and Brenda Dietrich (IBM), organizers of the special focus workshop on Yield Management and Dynamic Pricing, have collaborated to work on a special issue of the journal Production and Operations Management

Another example is provided by Special Focus co-organizer, Rakesh Vohra (Kellogg School of Management, Northwestern University), who says, "At one of the workshops I met with Jennifer Chayes and Christian Borgs of Microsoft Research which has resulted in a number of subsequent contacts that have proved fruitful in terms of new research problems as well as internship opportunities for students."

Participants often note the importance of getting feedback on their research at workshops, prior to its publication. Robert Day (University of Connecticut) presented work, which has recently been accepted for publication, at the Workshop on Computational Issues in Auction Design in October 2004. He notes that, "Because the audience included a broad group of experts and the seminar had only one track, the feedback from audience participants was very helpful in pinpointing what were the important open questions prior to publication [of our paper]."

The European Conference on Operational Research (EURO 2006) is one of the leading international conferences in operations research. It is widely regarded as a forum for communication and cooperation among European operations researchers who are active in diverse areas of operations research. The PI for this grant, Fred Roberts, and Special Focus participant, Stefan Pickl, both delivered semi-plenary lectures at the EURO 2006 conference, bringing topics related to the Special Focus to a wide audience. These talks are listed in Section VI.

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. Illustrative of this point are

several interactions and collaborations have already begun following the workshop on Polyhedral Combinatorics of Random Utility.

"The collaborative work that is coming out of this meeting will have deep implications for the decision sciences including psychology, economics, political science, operations research." *Michel Regenwetter (Department of Psychology, University of Illinois Urbana-Champaign)*

"I daresay that the workshop Polyhedral Combinatorics of Random Utility was very successful in bringing together researchers from different areas (for instance, mathematical psychology, combinatorial optimization and computational geometry) but studying the same objects." Samuel Fiorini *(Department of Mathematics, Université Libre de Bruxelles)*

Jean-Paul Doignon (Université Libre de Bruxelles), co-organizer of the workshop on Polyhedral Combinatorics of Random Utility, cites two specific collaborations between psychology and mathematics faculty that he has become involved with as a direct result of this workshop.

"I think it was good to have people from different areas speaking together. In particular, Tony Marley (Psychology, University of Victoria) raised a problem that has attracted the attention of three other participants: Samuel Fiorini (Mathematics, Université Libre de Bruxelles), Reinhard Suck (Psychology, Universität of Osnabrück), and myself. Since the workshop, we have been working on the problem, which amounts to characterizing a model of latent ranking, the so-called *best-worst model*. The model comes out of marketing where special questionnaires are used to collect from a customer information on his/her preference relation on a collection of alternatives. More precisely, the customer is repeatedly asked to provide his/her best and worst choices in a varying subset of the collection of alternatives. Mathematically, a model is defined to explain the customer's answers, based on his/her latent ranking of all alternatives. Assuming the latent ranking is a random variable, there results probability values for his/her possible answers. The problem is to characterize the probability values thus generated. This problem can be reformulated as the one of characterizing by linear inequalities a certain polytope of which only the vertices are known at the start. The four authors (including Tony Marley) have produced a set of working notes with partial results, but are still far from seeing a solution to the main problem and thus keep working on it." *Jean-Paul Doignon (Department of Mathematics, Université Libre de Bruxelles)*

"Another collaboration that started during the workshop involves Clint Davis-Stober and Michel Regenwetter, both from the Psychology Department at University of Illinois at Urbana-Champaign, and Samuel Fiorini and myself, both of the Mathematics Department, ULB. The talks of Davis-Stober and Regenwetter exposed a very interesting approach for assessing whether certain models used in psychology are confirmed or rejected with respect to collected choice data. The approach can be applied to various models of choice, but it still generates several mathematical problems. In particular, there are questions of an algorithmic nature, and also questions pertaining to convex geometry or combinatorics of relations. François Glineur (Economics, Université Catholique de Louvain) has now joined the team. We now see how to put together the contributions made by the members of the team, and hope to soon write up a paper with (tentative) title: New Approaches to the Analysis of Choice Data." *Jean-Paul Doignon (Department of Mathematics, Université Libre de Bruxelles)*

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 Polyhedral Combinatorics of Random Utility

- Diane David-Rus, Rutgers University
- Clint Davis-Stober, University of Illinois at Urbana-Champaign
- Nathanael Hyafil, University of Toronto
- Berit Johannes, ETH Zurich
- Gwenael Joret, Université Libre de Bruxelles
- Eva Schuberth, ETH Zurich

DIMACS Workshop on Information Security Economics

- Aaron Michael Johnson, Yale University
- Haibing Lu, Rutgers University
- Heechang Shin, Rutgers University

Graduate student, Gwenael Joret (Université Libre de Bruxelles), attended the Workshop on Polyhedral Combinatorics and Random Utility and notes, "I learned at that [workshop] open problems related to my research subjects."

There was strong 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 student Noam Goldberg is expressed in his own words:

"On October 25-28 I attended the DIMACS/LAMSADE Workshop on Voting Theory and Preference Modeling. Thanks to DIMACS' funding to travel to LAMSADE in Paris I was exposed to this exciting interdisciplinary field. I found great interest in many of the talks at the workshop. [The talk] *Computer Science and Decision Making* by Dr. Fred Roberts acquainted me with sequential decision making problems through the example of container inspection in sea ports. I recently started to study a related problem of least cost diagnosis of points of a Boolean discriminant /classification function."

This note from Stefan Pickl (Universität der Bundeswehr München) further notes the connection between this Special Focus on the Computation and the Socio-Economic Sciences and the LAMSADE program:

"In 2006, I visited several DIMACS conferences and workshops. A longer research stay at DIMACS is planned for 2007/2008. Furthermore an international research cooperation between LAMSADE and the University of Luxemburg (exchange of both diploma and Ph.D. students) will be established in the near future. This is a result of this important DIMACS program."

XI. Contributions to Resources for Research and Education

Stefan Pickl (Universität der Bundeswehr München) visited DIMACS as part of this Special Focus during May 2004. One of the outcomes that Pickl reported was the creation of a new multi-institutional 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 Health and Bio-Systems" was held on May 18-19, 2006 in Graz, Austria. Invited speakers included Prof. Klaus Lackner (The Earth Institute at Columbia University) "Energy Modeling and Sustainable Challenges" and Dr. Hans Georg Zimmermann (Siemens, Munich) about the Forecasting of New Energy Markets.

XII. Contributions Beyond Science and Engineering

Nina Fefferman (DIMACS/Tufts University) and Ramanan Laxminaranyan (Resources for the Future) are collaborating on the epidemiological implications of social organization. Fefferman's earlier work shows that certain social organization strategies require a sacrifice of either efficiency for safety, or vice versa, while other societal strategies provide the same or higher level of efficiency without sacrificing safety. This suggests that restructuring companies, schools and local populations can have a large impact on safety without sacrificing efficiency (e.g. capacity for work or money). Fefferman and Laxminaranyan have since been extending this research to investigate the impacts of disease spread based on the organizational structures of large businesses, with a goal of identifying resilient business structures.

Special Focus participant Stefan Pickl (Universität der Bundeswehr München) is involved in several research projects aimed at establishing optimal energy management within emission trading markets. The Kyoto Protocol of the UN Framework Convention on Climate Change (UNFCCC) calls for a new structure for greenhouse gas management that creates opportunities for new economic instruments for environmental protection, which can only be guaranteed if they are embedded in an optimal energy management and process optimization system. Several of Pickl's research projects study how financial markets provide economic incentives for better management of greenhouse gas emissions.