University of Massachusetts Amherst

Alum Matters

Vol. 4, No. 5 • Spring 2004

A newsletter for alumni of the Department of Computer Science

Making markets and democracy work

From within the confines of the Agent-Mediated Electronic Marketplaces Lab at Carnegie Mellon University's Computer Science Department, Associate Professor Tuomas Sandholm (Ph.D. '96) is leading research efforts that could affect the outcomes of such varied events as divorce settlements, product bidding, or presidential elections. Sandholm's research deals with computational approaches that make markets and democracy work.

"Game theory provides a basis for engineering the incentives into the interaction mechanism (e.g., rules of an election or auction) so that a desirable system-wide outcome (e.g. President, resource allocation, or task allocation) is chosen even though every agent acts based on self-interest," said Sandholm.

Sandholm addresses the practical computing, communication, privacy, and economic concerns of game theoretic mechanisms. "This is a particularly exciting research area because those issues are intimately intertwined," said Sandholm. "Whether you like it or not, preference aggregation settings are all around us." Preference aggregation is a problem of multiple agents jointly choosing an outcome, such as a President, task allocation, or a resource allocation. What makes it so difficult is that, generally, the agents have different preferences over outcomes, said Sandholm. This is a central problem in multiagent systems, be the agents human or software. *Mechanism design* is the art and science of designing the rules of the game so that the agents are motivated to report their preferences truthfully and a desirable outcome is chosen.

Voting is a general method for preference aggregation in multiagent settings, but a key problem with voting mechanisms is voter manipulation. "An agent is said to vote strategically when it ranks alternatives not according to true preference, but in order to manipulate the results so the outcome is ultimately more favorable to the agent," said Sandholm. "For example, if an agent prefers Nader to Gore to Bush, but knows that Nader has too few other supporters to win the 2000 Presidential election, while Gore and Bush are close to each other, the agent would be better off by declaring Gore as its top candidate. Manipulation is an undesirable phenomenon. If the agents reveal their preferences insincerely, a socially undesirable candidate may be chosen." Seminal economic impossibility results show that all voting protocols are manipulable. Sandholm's work takes the next step to designing protocols that are especially hard to manipulate. He designed voting mechanisms where finding a beneficial manipulation is so hard computationally, that although a manipulation exists, it is intractable. "Computational complexity can be used as a barrier to strategic behavior in settings where economic mechanism design falls short," said Sandholm.

According to Sandholm, the design of interaction mechanisms can be automated, and these yield better mechanisms than the best known to date. Applications for automated mechanism design include divorce settlement negotiations, public works project decisions, and dealmaking in auctions. Sandholm's design software created optimal mechanisms for divorce settlements (which spouse gets what as a function of their reported valuations of the items), for (combinatorial) public goods problems (e.g., for deciding whether to build a road, bridge, neither, or both), and for revenue-maximizing multi-object auctions (a tough open research problem).

Since 1997, Sandholm has also been working on algorithms for clearing complex auctions. In a combinatorial auction, bidders can bid on self-selected packages of items. Sandholm's research generalizes that idea to what he calls *expressive competition*. In that framework, bidders can express their offers in rich formats: package bids, item attributes, discount schedules, capacity constraints, etc. The bid taker can also be highly expressive about how her preferences should factor into the determination of

the winners of the auction. Her expressiveness includes side constraints (e.g., "I don't want more than 200 winners; more is too much hassle," "I don't want anyone to win more than 15%," "I want minorities to win at least 5%," ...), trade-off expressions, and statements about how item attributes and bidder attributes are to be taken into account. To enable expressive competition, algorithms are needed for winner determination, a hard combinatorial optimization problem. Sandholm has developed the fastest optimal algorithm for this problem. The hardest real-world expressive competition that Sandholm has encountered was a transportation services procurement auction with 22,665 trucking lanes to be bought, multiple units of each, 323,015 bids, and several side constraints. Sandholm's technology achieved (and proved) optimality in 5.5 minutes while the nearest competitor took 6 hours for a 97% optimal solution and didn't improve even after 68 hours. In other expressive competition events that Sandholm's technology has solved there have been over a million bids, over 110,000 side constraints, or over $750 million on the line. Expressive competition creates economic value, makes bidding easier, and is today technologically feasible, said Sandholm.

Are there yet unforeseen ways that computing and complexity can improve preference aggregation? Sandholm believes that there are, and his future research will focus on the achieving those improvements.

At the age of 35, Sandholm not only teaches and directs a research lab, but is also Founder, Chairman of the Board, and Chief Technology Officer of a successful company, CombineNet, with 70 full-time employees and 45 Fortune 500 clients. In the last two years, CombineNet has used Sandholm's expressive competition technology to clear $7 billion of procurement auctions, generating $1.2 billion in savings. (This savings is achieved through increasing economic efficiency, not through squeezing the suppliers' margins).

While a Ph.D. student at UMass Amherst, Sandholm was advised by Professor Victor Lesser. He is the 2003 recipient of the prestigious Computers and Thought Award, presented by the International Joint Conference on Artificial Intelligence (IJCAI), and the Sloan Research Fellowship, presented by the Alfred P. Sloan Foundation. He has also received several other prestigious academic awards, including the National Science Foundation CAREER Award in 1997 and the inaugural ACM Autonomous Agents Research Award in 2001. Sandholm has published more than 160 technical papers on electronic commerce, game theory, artificial intelligence, multiagent systems, auctions, automated negotiation and contracting, coalition formation, voting, safe exchange, bounded rationality, machine learning, and combinatorial optimization. Sandholm is not only a risk-taker in cutting edge research, but in personal life as well. He was once ranked 12th in the Worlds (1987) and #1 in Finland (1986) in windsurf racing, and continues to windsurf today, even after an encounter with a shark on the Cape Cod coast.

Erratum

In the *Alum Matters* section of the fall 2003 issue, we listed Jamie Callan's (Ph.D. '93) advisor as Bruce Croft. Callan's Ph.D. advisor was Paul Utgoff. We regret the error.

Alumni Connections

Rich Sutton (Ph.D. '84) has been appointed as the iCORE Chair in Reinforcement Learning in the Department of Computing Science at the University of Alberta. His research program will be a cornerstone of the new Alberta Ingenuity Centre for Machine Learning (AICML), which has recently been established in Edmonton. To develop the research program, Dr. Sutton has received a five year iCORE Chair and Professor Establishment (CPE) grant. Sutton joined the University of Alberta in August 2003 as Professor of Computing Science. Sutton's UMass advisor was Andrew Barto.

Henning Schulzrinne (ECE Ph.D. '93), Columbia University Associate Professor, was named one of the 50 most powerful people in networking by *Network World*. Schulzrinne, the only academic on the top 50 list, was advised by Professor Jim Kurose while a student at UMass.

The surveillance research of Computer Science alumnus **Rakesh Kumar** (Ph.D. '92), director of David Sarnoff Research Center's media lab, was highlighted in the "10 Emerging Technologies that will Change Your World" issue of MIT's *Technology Review* magazine. Kumar was advised by Professor Allen Hanson while a graduate student at UMass Amherst.

Another CS alumnus, University of Colorado at Boulder Professor **Alexander Wolf** (Ph.D. '85), was featured in the CU Engineering *Corporate Partner* newsletter for his direction of the Computer and Communications Security Center. Professors Lori Clarke and Jack Wileden were Wolf's advisors at UMass Amherst.

Alumni updates needed!

What have you been up to lately? Keep in touch with other alumni. Tell us where you are living and working and we'll include your information in **Alumni Connections**.

Email us at: alumni@cs.umass.edu. Thanks!