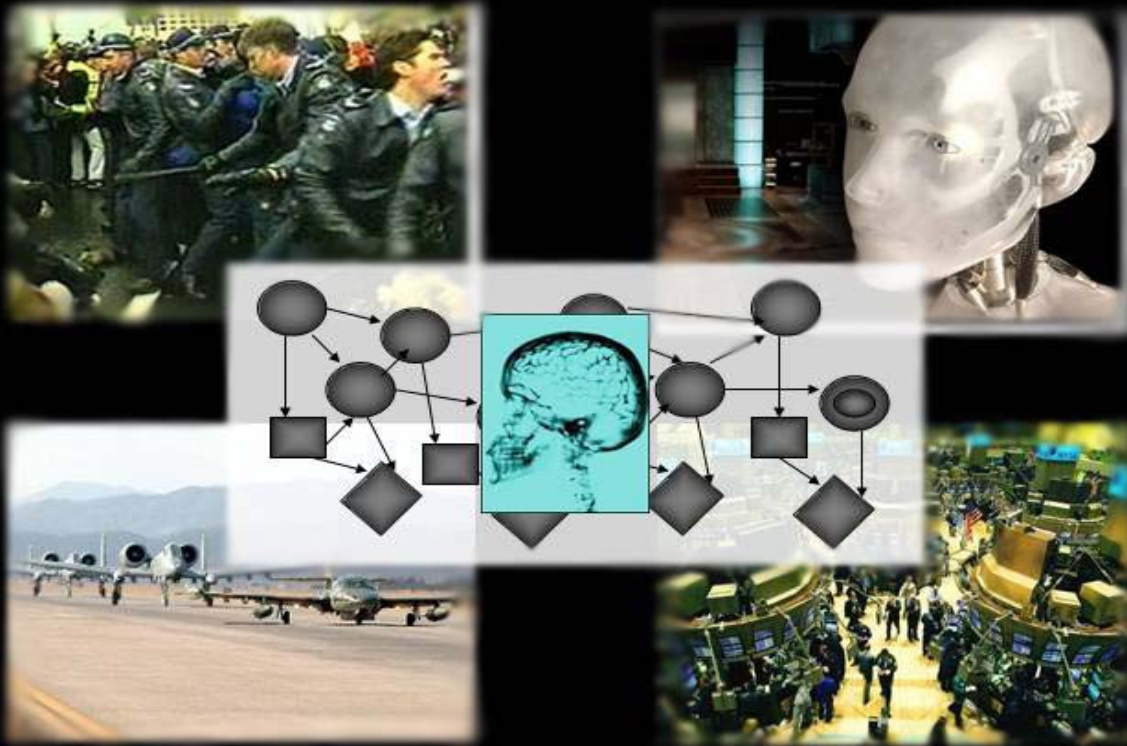
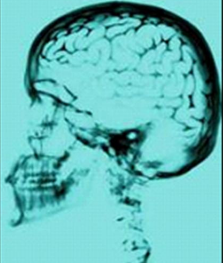


Tucson Workshop on Computational and Behavioral Decision Making

University of Arizona
Tucson, Arizona
February 28 – March 1, 2008



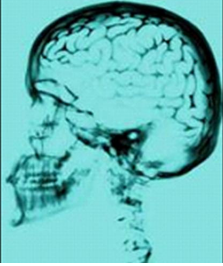


We gratefully acknowledge the support of the Air
Force Office of Scientific Research
Multidisciplinary University Research Initiative:
GRANT # F49620-03-1-0477



Organizing Committee:

Tamar Kugler, University of Arizona
J. Cole Smith, University of Florida
Young Jun Son, University of Arizona



Tucson Workshop on Computational and Behavioral Decision Making

Workshop Program Overview

Dress code for the meetings and dinners is casual

THURSDAY, FEBRUARY 28TH

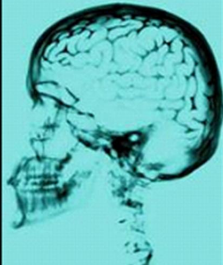
6:30 pm Dinner at Cuvee, 3352 E. Speedway, Tucson
<http://www.cuveeworldbistro.com/>

FRIDAY, FEBRUARY 29TH

(*Four Points Sheraton Hotel, 1900 East Speedway · Tucson, Arizona 85719*)

Breakfast will be provided at 8:00am

8:00 am- 8:30 am	Registration and Welcome
8:30 am- 10:00 am	David Mendonça: Group Decision in Emergency Response David Schkade: Are Judges Political? Ferenc Szidarovszky: Intergroup Conflicts: Equilibria and Stability
10:00 am- 10:30 am	Break
10:30 am - 12:00 pm	Lisa Ordonez: Incidental Emotions and Risk Tamar Kugler: Regret and Consequential Thought in the Trust Game John Lee: Dynamical Approaches to Modeling Trust and Cooperation of Multiple People and Multiple Elements of Automation
12:00 pm - 1:30 pm	Lunch (on your own)
1:30 pm – 3:00 pm	Judy Jin and Young-Jun Son: Decision Field Theory Extension for Dynamic Modeling of Human Decision Making Behavior Suvrajeet Sen: Shadow Prices and Robust Policies in Sequential Resource Allocation under Uncertainty Anton J. Kleywegt: Modeling and Learning in Settings with Modeling Error



Tucson Workshop on Computational and Behavioral Decision Making

Workshop Program Overview (cont.)

- 3:00 pm - 3:15 pm Break
- 3:15 pm - 5:15 pm **Ronald Askin:** Modeling Decisions in Complex and Risky Multistage Decision Processes
- Eric Smith:** Bar Examinee Mental Mistakes
- Terry Bahill:** 15 Years of Student Mistakes in Tradeoff Studies.
- Cole Smith:** Evacuation Problems with Human Behavioral Considerations

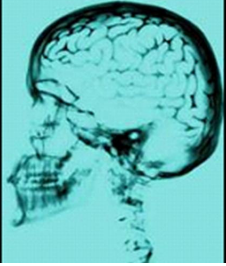
- 6:30 pm Dinner at Kingfisher, 2564 East Grant Road, Tucson
<http://kingfishertucson.com/>

SATURDAY, MARCH 1ST

(Four Points Sheraton Hotel, 1900 East Speedway · Tucson, Arizona 85719)

* Breakfast will be provided at 8 am*

- 8:30 am- 10:00 am **Terry Connolly:** Myopic Regret Aversion in Repeated Decisions
- Zur Shapira:** Reference Points Effects on Tradeoffs between Job Attributes
- Jerome Busemeyer:** Quantum Information Processing Explanation for Interactions between Inferences and Decisions
- 10:00 am - 10:30 am Break
- 10:30 am – 12:30 pm **Kevin Wood:** Stackelberg Games for Adversarial Risk Analysis and Management
- Akio Matsumoto:** Controlling the Cournot-Nash Chaos
- Haiyan Qiao:** Multi-agent Learning in Decision Making
- Jun Zhang:** TBA.



Tucson Workshop on Computational and Behavioral Decision Making

Abstracts
(In alphabetical order)

Modeling Decisions in Complex and Risky Multistage Decision Processes

Ronald G. Askin and Mengying Fu

Human decision makers are known to be affected by factors such as anchoring, certainty preference, approach-avoidance conflicts, risk aversion, and framing. However the majority of previous research has studied behavior in relatively simple decision situations with only a limited number of alternatives and decision stages. In these cases, rewards and final outcome probabilities could be determined and rationality of behavior judged. There is little information available on the effect of previous outcomes on choice consistency and risk perception or on the ability of humans to accurately estimate multistage risk probabilities. In this talk we discuss the response of human decision makers to random outcomes in multistage decision processes under risk. We investigate scenarios in which the optimal choices are not obvious but for which the decision maker has knowledge of the one step ahead outcome probabilities and may be able to infer good finite horizon solutions. The key questions of interest relate to 1) the ability of decision makers to understand and determine optimal or near-optimal choices in real-time for multistage probabilistic processes; 2) if decision behavior properties such as dynamic and consequential consistency hold in complex, multistage processes; and 3) whether series of lucky or unlucky outcomes affect risk aversion and the issues addressed in the above two questions. The results from a set of experiment collecting data from university students are reported. Experiments cover the cases of known and unknown horizon length and binary vs. graduated reward structures. Empirical models are constructed to describe the ability of participants to estimate optimal decisions and their discipline at selecting those choices. Prediction and consistency performance are modeled as a function of dynamic probabilistic outcomes and complexity of the residual finite horizon decision problem. The results indicate some but not most individuals react to recent outcomes. Also, individuals are best in selecting optimal outcomes for short or near infinite horizon problems.

15 Years of Student Mistakes in Tradeoff Studies

Terry Bahill, James Bohlman, Les Cano and Eric Smith

Tradeoff studies are broadly recognized as *the* method for simultaneously considering multiple alternatives with many criteria, and as such are recommended and mandated in the Capability Maturity Model Integration (CMMI) Decision Analysis and Resolution (DAR) process. The decision-making fields of Judgment and Decision Making, Cognitive Science and Experimental Economics have built up a large body of research on human biases and errors in considering numerical and criteria-based choices. Relationships between experiments in these fields and the elements of tradeoff studies show that tradeoff studies are susceptible to human mental mistakes. Smith, Son, Piattelli-Palmarini and Bahill (2007) postulated 28 specific mental mistakes that could affect the ten specific components of a tradeoff study. In the fall of 2007, we found and documented specific instances of these mental mistakes in student project documents and in professional published tradeoff studies.

Over the past 15 years, teams of seniors and graduate students in Bahill's Systems Engineering courses wrote the eight Wymorian system design documents for a particular system. This document set contains the problem statement and tradeoff studies. At the end of the semester, the students submitted their final set of documents. On average, these documents took 100 man-hours to write and comprised 100 pages each. We examined these projects looking for our 28 specific mental mistakes. We found instances of most of these mental mistakes. The most common mistakes were in the problem statement area. This paper presents selected examples of these mistakes.

A simple example of the type of mistakes that we found comes from the students' Spin Coach documents. The Spin Coach is a system that teaches batters how to see the spin on a baseball and to predict the direction of spin-induced movement. However, it would be hard to measure this learning. Therefore, most student teams substituted another attribute for learning: they used the subject's batting average or other things that were easy to measure such as reaction time. Students repeatedly copied a method of conducting a sensitivity analysis from a legacy tradeoff study published in the course textbook. Despite warnings about the inadequacy of that sensitivity analysis, students conducted their analyses in that very same way. This was an example of the Forer effect. Students failed to question a sensitivity analysis that was presented by a perceived authority and was seemingly adaptable to their own tradeoff study.

It was observed that many times a problem was not expressed in a way that would invite a solution. That is, a deficiency was not given, nor a reason why the deficiency should be remedied and who would benefit. It was as if the projects' authors were being politically correct or did not know how to write a problem statement.

Alternatives should ideally be evaluated based on independent evaluation criteria. Students often choose dependent criteria. When scoring these criteria for the different alternatives, having multiple dependent criteria could tend to magnify or diminish the final score of the alternatives, thus leading to preferring the wrong alternative.

It was common for students not to seek outside advice or guidance in the course of performing their tradeoff studies. If they had sought this guidance, expert review or opinion, they might have avoided the errors we detected in their tradeoff studies. This would most likely be the case if the guidance concerned the tradeoff study itself (not just the technical matters) and elicited high-quality examination of all tradeoff study components.

Quantum Information Processing Explanation for Interactions between Inferences and Decisions

Jerome Busemeyer

Markov and quantum information processing models are compared with respect to their capability of explaining two different puzzling findings from empirical research on human inference and decision making.

Both findings involve a task that requires making an inference about one of two possible uncertain states, followed by decision about two possible courses of action. Two conditions are compared: under one condition, the decisions are obtained after discovering or measuring the uncertain state; under another condition, choices are obtained before resolving the uncertainty so that the state remains unknown or unmeasured. Systematic departures from the Markov model are observed, and these deviations are explained as interference effects using the quantum model.

Decision Field Theory Extension for Dynamic Modeling of Human Decision Making Behavior

Judy Jin and Young-Jun Son

Understanding and modeling of human decision behaviors is crucial to help improve the future decisions. Decision field theory (DFT), widely known in the field of mathematical psychology, provides a mathematical model for the evolution of the preferences among options of a human decision-maker. The evolution is based on the subjective evaluation for the options and his/her attention on an attribute (interest). This research aims to extend DFT to effectively represent dynamic characteristics of the human decision process under a time varying environment. For this purpose, a new integrated modeling framework has been developed, which uses two different time scales to represent a human deliberation process during decision making, i.e., micro process and macro process. In the macro process, differently from the existing approach by pre-specifying an expected attention weight in a DFT model, this paper is at the first time to develop an adaptive learning method to estimate the human expected attention weights by fitting a DFT model to match with the available human decisions sequentially. In the micro process, the inherent linkage between the expected attention weights and the decision choice uncertainty has been investigated. The upper and lower bounds of the expected attention weights are estimated and adaptively narrowed based on the sequential measurements of the attributes under a dynamic environment. The proposed modeling method has been discussed in detail for a typical decision scenario with two alternatives and two attributes. Both, simulations and a case study, have been conducted in this research to demonstrate the effectiveness of the proposed modeling approach. To enhance the generality of the proposed method, it and its variation have been applied to various complex and dynamic scenarios, including 1) error detection and resolution personnel in a complex manufacturing facility, 2) evacuation behaviors under a terrorist bomb attack, and 3) evacuation behaviors under fire in a factory. The results are quite promising.

Modeling and Learning in Settings with Modeling Error

Anton J. Kleywegt

A widely used approach in decision support is to formulate a model that approximately describes the decision situation, and to study or solve the model to obtain results that help with decision making.

Often models have parameters, and the correct values of the parameters are not known. If the model is used repeatedly, it seems reasonable to collect data each time the model is used, and to update the parameter estimates before using the model again. An important question in such a setting is what properties the resulting dynamical process has, for example, whether the sequence of estimates converges to a good value. Such questions have been addressed in many settings where it was assumed that the structure of the model is correct, that is, there exist values of the parameters that make the model correct.

In such settings it is often studied under what conditions the parameter estimates converge to the values that make the model correct, and how much cost, due to suboptimal decisions, is incurred during the process. The setting in which the model is not correct and parameter values are estimated while decisions are made, has attracted less attention. In such a setting it does not even make sense to ask whether the parameter estimates converge to the values that make the model correct, because there does not exist such values. Rather, questions are asked regarding convergence of parameter estimates to any limit, whether the performance of the resulting decisions improve or deteriorate as parameter estimates are updated, whether the decision maker can be expected to detect the error in the model, and how favorable or unfavorable such a limit is to the decision maker relative to the situation in which the correct model is known. The answers of many of these questions are still open, even for problems that seem simple. The talk will provide an overview of some of the research that addresses modeling and learning in settings with modeling error.

Regret and Consequential Thought in the Trust Game

Tamar Kugler, Terry Connolly and Edgar Kausel

In the Trust Game, a Sender receives a monetary endowment, and can transfer any or all of it to a Responder, who receives triple the amount sent, and can then return any part of it to the Sender. Rationality predicts no transfer: The Responder has no incentive to return any part of the money she receives, so the Sender has no incentive to send any. However, in actual experiments both players typically make positive transfers. When returns are (or might be) positive, the Senders' decision as to how much to send becomes unexpectedly complex, and the assumption that it approximates expected utility maximization is highly implausible. Instead we suggest that Senders' decisions generally result from a blend of conflicting motivations, partial problem framings and undisciplined probability assessments. This implies that modest interventions that help Senders to structure their thinking about the problem may have substantial impact on the amount they send. This study examines the effect of two such interventions on Senders' behavior: priming of regret considerations, and assistance in consequential thinking. In Experiment 1 (N=128), Senders were primed, before deciding how much of a \$20 endowment to send, to consider the possibility of experiencing regret as a result of either under-trusting or over-trusting the Responder. In Experiment 2 (N=64), Senders engaged in a brief consequential thinking exercise before making their transfer decision. In both experiments the amount sent following any of these manipulations was substantially smaller than that sent by unprimed controls. These results support the view that Sender behavior in most Trust Game experiments results from muddled and incomplete thinking and is unlikely to yield conceptually clear measures of trust, altruism, equity-seeking or any other motivation.

Dynamical Approaches to Modeling Trust and Cooperation of Multiple People and Multiple Elements of Automation

John D. Lee

To control many complex systems people have to rely on multiple elements of automation and cooperate with multiple geographically-distributed people. Such systems range from fleets of remotely piloted vehicles and aircraft in commercial air space to global supply chains. These multi-operator multi-automation systems succeed according to how appropriately operators rely on automation, and also according to whether operators cooperate. Understanding the behavior of such systems is difficult because the dynamical interactions between the elements lead to complex and counter-intuitive behavior. A series of models have been developed to describe operators' decisions to rely on automation and their decisions to cooperate with other operators (Gao & Lee, 2006a, 2006b). These models extend Decision Field Theory (Busemeyer & Townsend, 1993) to capture the dynamics of sequential decisions in which one decision changes the context for subsequent decisions. Specifically, an individual's trust in the automation and individual's trust in the other operators guide the decision to rely on automation and cooperate with other operators. This trust is subsequently affected by the decision to rely and cooperate, which in turn affects subsequent decisions to rely and cooperate. These models predict changes in trust associated with failures of the automation and account for patterns of reliance seen with different interface manipulations. These models also account for patterns of cooperative and competitive behavior seen in a prisoners' dilemma game theory scenario, such as the vicious cycles, in which cooperative behavior devolves into competitive behavior.

The model shows that appropriate reliance on automation and sharing of automation-related information between operators can improve performance and cooperation, a result confirmed with a microworld experiment. One type of automation-related information concerns the performance of the automation. Sharing this information allows other operators to develop more appropriate trust in the automation, improve reliance on automation, and consequently reduce unintentionally competitive behavior, which increases trust in the other operator and increases cooperation. Sharing information regarding the reliance on automation reveals whether it was the other operator or the automation that generated the apparently competitive behavior, which leads to a more accurate interpretation of the other's intent to cooperate, and consequently promotes greater trust and cooperation. The increasing prevalence of multi-automation multi-operator systems makes dynamical models of their behavior increasingly important.

These models have several benefits: they focus hypotheses and identify useful experimental conditions, they support interpreting data from experiments, and they extrapolate experimental data to explore a variety of experimental conditions that would not be economically feasible otherwise.

Controlling the Cournot-Nash Chaos

Akio Matsumoto

The recent developing theory of nonlinear dynamics shows that any economic model can generate complex dynamics involving chaos if its nonlinearities become strong enough. This study constructs a nonlinear Cournot duopoly model, reveals conditions for the occurrence of chaos, and then considers how to control chaos. The main purpose of this paper is to demonstrate that chaos generated in Cournot competition is in a double bind from the long-run perspective: a firm with a lower marginal production cost prefers a stable market to a chaotic market while a firm with a higher marginal production cost prefers the chaotic market to the stable market.

Group Decision in Emergency Response

David Mendonça

Observations of group decision at the frontier of human experience promise insights into the nature of collective creativity and joint expertise. In the case of decision making by groups of emergency response personnel, prior experience is expected to be relevant, despite the sometimes considerable difference between those experiences and the situation at hand. Understanding how these experiences are used (or misused) in the course of the response should deepen our insights into how groups make high stakes, time-constrained decisions.

This talk reviews work in developing models of the cognitive processes that underlie decision making by individuals and groups in response to highly non-routine situations. The focus of the talk is on explaining the impact of time constraint and event severity on how small, multidisciplinary groups of response personnel develop and deploy new procedures to address large-scale emergencies. This research involves field and archival study of professional response to emergencies, complemented by more focused approaches employing laboratory experimentation and computational modeling. Illustrative results are drawn from field study of infrastructure restoration following the 11 September 2001 World Trade Center attack, as well as experimentation involving response personnel in the US and abroad. Preliminary results on computational modeling of individual-level cognition in this context are briefly reviewed.

Incidental Emotions and Risk

Lisa Ordóñez, Tamar Kugler and Terry Connolly

This paper presents two experiments that examine the influence of incidental emotions on risk-related behavior in individual and interactive settings. Moods were induced using a writing task in which participants completed a brief essay describing a situation in which they strongly felt a specific emotion. Four between-subject mood conditions were used: anger, fear, sadness, and happiness. In the first experiment, we measured risky choices with known probabilities: participants were asked to make a series of choices between high risk and low risk gambles (using Holt and Laury's 2002 risk attitude questionnaire). We find that angry people are less risk averse than happy and sad people, and that fearful people are the most risk averse of all groups.

These results are consistent with Appraisal-Tendency Framework (ATF) (Lerner & Keltner 2000; 2001) which predicts that emotions evoke particular appraisal tendencies that affect our subsequent decision making (even when the emotions are incidental to the decision at hand). Lerner and Keltner assume that fear arises from appraisals of profound uncertainty: a sense that even basic needs such as safety are uncertain and that situational factors beyond one's control shape outcomes. By contrast, anger arises from appraisals of certainty and individual control: a demeaning offense occurred with certainty and the situation is under the control of human agency. Since sadness neutral with respect to certainty (Smith & Elsworth, 1985), sad participants should be between fear and anger in terms of risk aversion. Thus, the prediction is that individuals experiencing fear will be more risk averse than those feeling anger, with sadness between these two (which is consistent with our data).

In the second experiment we examined risk-taking in interactive decisions, where outcomes depended not only on Nature but also on a decision of another agent – so that probabilities were both uncertain and strategically determined by others. Both experiments are unique in the field of emotion and decision making because they measure actual, incentive compatible behavior and not just behavioral intent, and because they focus on specific emotions and not just valence (positive and negative affect). Results from this ongoing research will be presented.

Multi-agent Learning in Decision Making

Haiyan Qiao

Learning in the natural world occurs when an agent, which perceives its current state and takes actions, interacts with unknown environment, which in return provides a positive or negative feedback. Research of reinforcement learning studies such processes and attempts to find policies that map states of the world to the actions the agent ought to take in those states for maximizing cumulative reward for the agent over the long run. In multi-agent systems, agent learning becomes more challenging, since the optimal action of each agent generally depends upon the actions of other agents. This talk provides an introduction to the problems in multiagent learning. The framework and basic concepts in multiagent reinforcement learning will be covered, followed by a brief introduction to a variety of approaches currently being studied by researchers. Most existing multiagent learning research focuses on non-cooperative games where equilibrium is a learning objective. However, in many situations, the equilibrium gives worse payoffs to both players than their payoffs would be in the case of cooperation; therefore the agents have strong desire to choose a cooperative solution and reach a win-win situation. I will introduce a multiagent learning model with bargaining that is well suited to cooperative games, and present some experimental results. The results show that the solution is unique and Pareto-optimal, as well as computationally efficient compared to equilibrium based solutions. I will also talk about learning in multi-agent systems with asymmetric agents who have different powers in decision making. The approach will be illustrated by applying it to classic economic model, which is known as oligopoly

Myopic Regret Aversion in Repeated Decisions

Jochen Reb and Terry Connolly

Regret over a poor decision outcome is exacerbated when one learns of a better outcome one would have received by choosing another alternative. This *outcome regret* can sometimes be avoided by shielding oneself from such feedback. However, in repeated decisions, this feedback can enhance learning and thus lead to making better (less regrettable) decisions in the future. This raises the possibility that decision makers may become trapped by *myopic regret avoidance* in which rejecting feedback to avoid short-term outcome regret leads to reduced learning and greater long-term regret over continuing poor decisions. We demonstrate this effect in two laboratory experiments (N=36 and 58) in which participants made repeated choices among uncertain monetary prospects. We then show in two further experiments (N=79 and 77) that the tendency to avoid feedback was reversed when decision makers were sensitized to *self-blame regret*, or regret over an unjustified decision. We discuss the findings in terms of a distinction between two regret components, one associated with outcome evaluation, the other with the decision process used in making the choice. The first can lead to entrapment, the second to decision enhancement.

Are Judges Political?

David Schkade, Cass Sunstein, Lisa Ellman and Andres Sawicki

There is much controversy in Washington over the role of ideology in judicial decision making, and we set out to collect some empirical evidence to find out how much difference it actually makes once they are on the bench. We studied thousands of votes by federal appellate judges, who are randomly assigned to three-judge panels, which then make decisions by majority vote. Focusing primarily on recent cases (since 1980) and on case categories that would seem to be polarized (e.g., affirmative action, abortion, sexual discrimination) we looked for situations in which ideological differences should manifest themselves if they exist. As it turns out, ideology does matter - judges appointed by Republican presidents show somewhat more conservative voting patterns, while Democratic appointees are somewhat more liberal (although the difference is perhaps smaller than one might expect). The most striking lesson of our research, however, is the influence of judges on each other. For both Democratic and Republican appointees, the likelihood that they will cast a liberal vote jumps when the two other panel members are Democrats, and drops when the two other panel members are Republicans. We link this group dynamic to the well known research on group polarization and discuss implications for policy.

Shadow Prices and Robust Policies in Sequential Resource Allocation under Uncertainty

Suvrajeet Sen

Static resource allocation problems have a long history of having shadow prices guide decision-making processes. For sequential resource allocation models however, the use of shadow prices is far less common. However, the need for shadow prices becomes far more critical for resource allocation under uncertainty. In this talk, we will summarize our MURI research on developing shadow prices and robust policies using ideas emanating from stochastic programming.

Reference Points Effects on Tradeoffs between Job Attributes

Zur Shapira

Making tradeoffs is an important element of choosing among multi-attribute alternatives, but there are not many empirical studies that examined how people make such tradeoffs. Raiffa and Keeney (1968) proposed that attribute importance can be assessed when comparing two multi-attribute options, both identical on $(n-1)$ attributes that are put at their worst level, while the n^{th} attribute is at its worst level in one option and at its best level in the other. They argued that in going through all the possible comparisons this way, the importance of each attribute can be assessed and a multi-attribute utility can be estimated. Yates and Jagacinski (1980) argued that instead of the worst level, the reference option should be put at the "typical" level of the attributes. Shapira (1981, 1987) studied the way managers made tradeoff judgments between job attributes from their "current" positions that served as reference jobs. Additional studies cast doubt about the ability to create tradeoffs between options' attributes in a "rational" manner.

This paper expands the number of "reference" jobs and reports the results of a series of studies that examined the ways MBA students who were actively searching for jobs, made tradeoff judgments between attributes of hypothetical jobs. Four different job attributes were identified by interviewing a sample of MBA students who were looking for jobs but did not participate in the main study. To examine the effects of different reference points on tradeoffs, subjects initially described, on graphical rating scales their ideal, realistic and worse jobs in terms of the above attributes. These jobs and their attribute levels were defined by the students after they have acquired some experience with the job market. They then made bilateral tradeoffs between each of the above attributes from each of the three hypothetical reference jobs. The raw tradeoffs judgments were then used to derive a set of tradeoff coefficients for each reference job for each subject. Attribute importance was determined from those tradeoff coefficients and was then tested against other measures of importance, such as ranking. In addition, those importance measures were then correlated with subjects' preferences among hypothetical (mixed) jobs that were "offered" to them, that is, a job could be described as having the highest level on say attribute i , and the lowest on attribute j .

The results showed a marked effect of reference points on tradeoff judgments. The results are discussed in terms of the sensitivity of the elicitation procedure to the effects of reference points and reference jobs, and the question whether measuring overall preference order among job attributes is feasible.

Evacuation Problems with Human Behavioral Considerations

J. Cole Smith

Many network optimization problems assume static travel times (those that remain constant throughout a network's evacuation), simultaneous flows (assuming that all entities travel through the system at the same time), and strict capacity limitations on arc pathways. In the context of evacuation networks, however, travel times may vary with emergencies, or arcs may cease to exist altogether. Moreover, these times may indeed increase or decrease due to conditions imposed by emergencies. Flows are non-simultaneous, since people may begin their evacuations at different times; even in the case where people immediately exit, they will arrive on common arcs at different times. Capacities are elastic, and can be violated at the cost of an increase in travel time. Moreover, linear cost models on evacuation networks do not typically make sense, because evacuation is often neither a convex nor a concave function of time. For instance, in case of hurricane preparations, immediate evacuation is not necessarily preferable to evacuation 24 hours into the process. However, the danger of evacuation may increase in a convex manner as the storm appear, and then abate in a concave manner after the storm has passed.

One final practical concern is that flows can often not be split dynamically (one would imagine instructing 20 people fleeing a burning building to move to the left, while the other 5 people move to the right).

In response to this situation, we have constructed a time-indexed model capable of designing network evacuation trees, which considers stochastic travel times and populations in the network, builds in delays due to capacity restrictions, and enforces a non-split flows before the time of the disaster (akin to posting evacuation signs in a building or evacuation routes on highways). This problem is solved effectively using Benders decomposition and an inferred-dual-recovery scheme to circumvent the large-scale nature of time-indexed models.

However, our model treats evacuees as non-thinking agents, and ignores the inevitable free will (and often panic) exhibited in evacuation scenarios. Moreover, in certain emergency scenarios, the posted evacuation plan could be impossible to follow. Consider for instance the destruction of a bridge over which evacuees are asked to cross, or a burning hallway through which individuals fleeing a burning building are asked to traverse. Even under milder evacuation conditions, it is likely that some portion of the individuals will ignore evacuation instructions and follow a plan that seems logical.

Therefore, generally speaking, the problem at hand should be to minimize some evacuation penalty function, given that posted evacuation instructions merely influence, but do not dictate, the evacuation of the system. This talk will discuss the behavioral modeling and solution issues that confront our study of this problem, along with our early modeling efforts in this vein.

Bar Examinee Mental Mistakes

Eric D. Smith

The Bar Examination stands out as a singular gate before the practice of law, testing potential attorneys on their understanding of law and legal reasoning. The exam determines whether a student's investment in a legal education will be rewarded with the opportunity for compensated employment in the profession. Mental mistakes can mislead the search for correct answers in the multiple-choice sections, as well as in essay-format sections. The high pressure testing environment can exacerbate and compound the effects of mental mistakes.

The Bar Examination is given in different formats in different states. It is usually comprised of two days of testing, with about half of the testing being in multiple-choice format, and the other half in essay format sections. In California, the Bar Examination includes an additional day of Performance Tests, which are tests of simulated legal case work. The community of practicing lawyers is highly interested in the proper formulation of the exam, and the quality of the current examinees, and so creates a challenging yet fair test of mental abilities. The Bar of lawyers, as a guild, oversees the admittance of new members.

The Bar Examination has prompted the creation of many specialized preparatory courses, sometimes requiring an additional two months of class and homework, that not only review black letter law, but identify common pitfalls that affect test takers. Experienced lawyers and law school professors are often hired to deliver these exam-preparation courses. Some of the professors may have been previously involved in the writing of Bar Examinations, or in their scoring. Law professors in particular are noted for their ability to write correct, but potentially misleading questions, as they have years of experience in correlating the effects of question structure on examinee performance. This paper augments Bar Examination mental mistakes literature by providing a more complete coverage of specific mental mistakes, with some illustrative examples. As such, it is a specific instance of general examination planning that in a broader context can be used in preparation for significant examinations in different subjects and settings. Specifically, the paper describes the structured mental steps that optimize mental performance in the testing environment. The results, conclusions and recommendations can in general be used to aid in the correct analysis of sets of related facts presented in high stress and time-constrained environments.

Intergroup Conflicts: Equilibria and Stability

Ferenc Szidarovszky

A game theoretical model of intergroup conflicts is revisited in which members of each group contribute to secure a public good which becomes then available to all members regardless if they contributed or not, and the groups compete for an exogenous prize simultaneously. We first show that the best response of each player is equivalent to that in oligopolies with isoelastic price and linear cost functions. Then a complete equilibrium analysis is given showing that, except in a very special case, there is a unique equilibrium. And finally, a dynamic extension of the game is introduced and analyzed, where the players are able to increase their contributions at any time during a given time period.

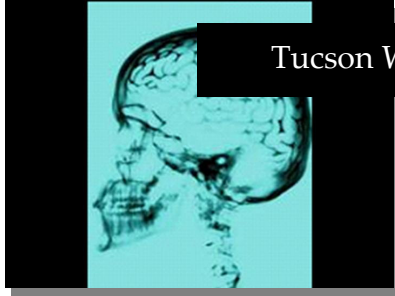
Stackelberg Games for Adversarial Risk Analysis and Management

Kevin Wood

Warfare, homeland-security and business operations require the assessment of risk that an intelligent adversary, or *attacker*, poses to those operations. We propose bilevel (sequential) Stackelberg games for assessing risk and trilevel extensions for planning defenses to minimize that risk. This talk thus offers an adversarial as opposed to standard (and largely inadequate) probabilistic models of risk analysis and risk management. It provides examples of such models for pipeline networks, electric power systems, industrial projects, and bio-terror defense. It describes mathematical models and offers solution procedures.

At the outer level of our bilevel risk-assessment model, the attacker seeks to maximize damage to the *defender's* operations or "system" by finding and attacking critical system components with his limited resources; at the inner level, an "industry-standard" optimization model measures system functionality and thereby damage. Components that the bilevel model suggests for attack are identified as "at risk." To minimize risk, a trilevel model adds an additional decision level to guide the defender's application of limited defensive resources for hardening system components, adding component redundancy, etc. All models presume perfect information for both attacker and defender.

An expert in probabilistic risk analysis might object to our (bilevel and trilevel) adversarial models' deterministic, worst-case assumptions. Will an attacker really be able to find a system's weakest points? What about the defender's uncertainty as to the attacker's motives and the effects of random events? We show how you, the defender, could incorporate uncertainty into our models to create a so-called "probabilistic risk-assessment model" —if you don't mind leaving yourself open to catastrophe.



Tucson Workshop on Computational and Behavioral Decision Making

Participants

WORKSHOP SPEAKERS

Jerome Busemeyer, Indiana University
Anton Kleywegt, Georgia Institute of Technology
John Lee, University of Iowa
Akio Matsumoto, Chuo University, Tokyo
David Mendonça, New Jersey Institute of Technology
Lisa Ordóñez, University of Arizona
Haiyan Qiao, California State University San Bernardino
David Schkade, UC San Diego
Eric Smith, University of Missouri at Rolla
Zur Shapira, New York University
Kevin Wood, Naval Post Graduate School
Jun Zhang, University of Michigan

LOCAL TEAM

Ronald Askin (Engineering), Arizona State University
A. Terry Bahill (Engineering), University of Arizona
Terry Connolly (Eller College), University of Arizona
Jionghua "Judy" H. Jin (Engineering), University of Michigan
Tamar Kugler (Eller College), University of Arizona
Amnon Rapoport (Eller College), University of Arizona
Suvrajeet Sen (Engineering), Ohio State University and University of Arizona
J. Cole Smith (Engineering), University of Florida
Young Jun "Son" Son (Engineering), University of Arizona
Ferenc Szidarovszky (Engineering), University of Arizona



❖ Thrust A: Sequential Decision-Making

● Research Scope

In this thrust area, we investigate systematic and replicable patterns of behavior in an attempt to formulate descriptive models that are psychologically interpretable, have potential practical implications, and can better account for human decision behavior. These studies range from theoretical underpinnings to the exploration of new decision-making theories on human subjects. In most cases, the data are collected to support our studies by presenting financially motivated subjects, whose payoff is contingent on their performance, with various decision scenarios that simulate or otherwise capture major ingredients of real decision making situations.

● List of Participants

Faculty: Terry Connolly, Tamar Kugler, Amnon Rapoport

Graduate Students, Post-Doc Students, Visiting Scholars: N. Bearden, R. Murphy, W. J. Becker, H. Otsubo, B. Kim, W. E. Stein, T. Daniel, E. Gisches, J. Reb, E. Kausel, E.E. Kausel, D. Butler

❖ Thrust B: Computational Decision-Making Models and Algorithms

● Research Scope

This area covers several computational aspects associated with decision-making, and in some cases, our computational research suggests experimental with human/animal subjects, whereas in others, we consider simulation experiments. The specific themes that we are investigating within this thrust area include computational models of human decision-making processes, decision-making based on game theoretic models, and models and algorithms for decision-making under risk and uncertainty. These themes provide a comprehensive framework for computationally oriented decision making research.

● List of Participants

Faculty: Ron Askin, Judy Jin, Suvrajeet Sen, Young-Jun Son, Ferenc Szidarovszky
Graduate Students, Post-Doc Students, Visiting Scholars: Z. Zhou, J. Desai, K. Huang, L. Ntaimo, Y. Yuan, T. Genc, Jijun Zhao, Jingjie Long, Akio Matsumoto, Haiyan Qiao, Mahdi Zarghaami, Erin Fitzpatrick, Mengying Fu, Shravan Krishnan, Paula de Szoeki, Liangjie Xue, Xiaobing Zhao, Seungho Lee, Parag Sarfare, Andres Abad, Binyuan Chen

◆ Thrust C: Network Decision-Making Research

● Research Scope

Research in this area encompasses both descriptive and prescriptive decision-making research in the field of networks, with a particular interest on network interdiction and secure network planning problems. The themes in this thrust area include network design, path planning, and even human decision-making behavior over congested networks. We have also designed a decision-making game in which networks can be designed by one player, and activities can be thwarted by another player. This software is flexible enough to allow either humans or algorithms to act as players. The purpose of such an exercise is to better understand relationships between human decision-makers and computational methods based on optimization or game theory.

● List of Participants

Faculty: Cole Smith, Tamar Kugler, Suvrajeet Sen, Simge Kucukyavuz
Graduate Students, Post-Doc Students, Visiting Scholars: April Andreas, Siqian (May) Shen, Churlzu Lim, Fransisca Sudargho, Chisonge Mofya, Benjamin Armbruster, Manish Garg, Balaji Ganesan, Arvind Natarajan

◆ Thrust D: Applied Decision-Making Research

● Research Scope

The goal of this thrust is to develop a high fidelity, synthetic human decision-making model under complex and realistic environments such as military command and control systems, automated manufacturing systems, and individual behaviors under emergency situations. The availability of such a model will allow us to understand and/or evaluate dynamics of systems involving humans more accurately. In this research endeavor, a number of engineering methodologies and technologies have been employed to help reverse-engineer (understand and extract features from) human behaviors, to represent the human decision-making model formally, and to develop a realistic simulated environment.

● List of Participants

Faculty: Terry Bahill, Judy Jin, Young-Jun Son
Graduate Students, Post-Doc Students, Visiting Scholars: Andres Abad, Eric Smith, James Bohlman, Xiaobing Zhao, Seungho Lee, Ameya Shendarkar, Karthik Vasudevan