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In This Issue

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Defending Against Ballistic Missile Attacks

The United States will defend itself, and its allies, from theater ballistic-missile (TBM) attacks. Anti-missile defenses currently include Navy ships with interceptor missiles and Army ground-based interceptors, although additional options are under study. The key question is: Where do we best position our anti-missile platforms to defend against a TBM attack? In "A Two-Sided Optimization for Theater Ballistic Missile Defense," G. Brown, M. Carlyle, D. Diehl, J. Kline, and K. Wood answer by developing a bilevel optimization that positions these platforms to minimize the maximum expected damage that an adversary can inflict, even when this adversary can see all defensive preparations. The basic model defines a "defender" and an "attacker" who can view each other's plans, but model variants can help determine the value of secrecy or deception to either side. The U.S. Navy is currently testing and refining this decision-support tool for introduction to the fleet.

Fast and Accurate Exotic Option Pricing

Exotic options, including barrier and lookback options, allow investors to effectively hedge against, or speculate on, the fluctuations of asset prices, exchange rates, or interest rates. Most exotic option contracts involve discrete monitoring (e.g., daily or weekly) of the underlying asset price or rate. Discrete monitoring can lead to significant price differences compared with traditional formulas based on continuous monitoring. The development of efficient numerical methods for pricing these exotic instruments is an important problem for investment banks, corporate treasury departments, and hedge funds. In "A Double-Exponential Fast Gauss Transform Algorithm for Pricing Discrete Path-Dependent Options," M. Broadie and Y. Yamamoto develop numerical methods for pricing these exotic options that are orders of magnitude faster and more accurate than previously available methods.

The Curse of Uncertainty in Dynamic Programming, and How to Fix It

Dynamic programming methods have been very successful for solving discrete-space, discrete-action control problems in which the system's stochastic behavior is an important characteristic. However, in any real-life situation, the problem "data"—in this case, transition matrices that describe how the states evolve when a specific action is taken—is unreliable and subject to estimation errors. Unfortunately, the optimal solution delivered by dynamic programming methods is often extremely sensitive to errors in the transition matrices, which limits the practical relevance of these approaches. In their paper, "Robust Control of Markov Decision Processes with Uncertain Transition Matrices," A. Nilim and L. El Ghaoui have uncovered the above "curse of uncertainty" inherent in these algorithms, and propose an elegant solution to the problem. The ingredients of the approach include a rigorous "robust control" framework to address the uncertainty issue; a simple proof of the corresponding "robust dynamic programming algorithm"; and models of data uncertainty that are both statistically accurate and computationally attractive. The resulting algorithm can be implemented with a computational cost that is almost the same as the original recursion, yet provides far more robust solutions. A practical example related to air traffic routing demonstrates that a substantial amount of robustness is gained at a small decrease in optimality.

New Market Equilibrium Formulation for the Natural Gas Sector

Recent deregulation and reconstruction of energy markets have had dramatic impacts on this vital sector of the economy. In the U.S., various regulatory actions have allowed these changes to take place. These regulatory changes were introduced to foster more competition in energy markets to benefit consumers due to increased market efficiencies. However, the actual results have not always turned out as expected (e.g., the California energy crisis). In "A Mixed Complementarity-Based Equilibrium Model of Natural Gas Markets," S. A. Gabriel, S. Kiet, and J. Zhuang examine the new natural gas market by developing an appropriate game theoretic model expressed as a nonlinear complementarity problem. This model is novel in its level of detail for the market participants along the natural gas supply chain as well as seasonal detail within the game theory framework. Three cases highlight the type of analysis of which this model is capable and show that it is a valuable tool for both public and private sector energy organizations.

Protecting Privacy Information in Statistical Tables

Statistical disclosure control is a primary activity in all the statistical agencies. Data has been collected from respondents under the agreement that their private information will not be released. By aggregating data and producing tables, statistical agencies aim to produce nonconfidential information. Because some particular cells in the tables can still release precise data pertaining to individual entities such as persons or businesses, some methodologies exist to avoid this situation and guarantee the publication of protected tables. The common aim in all the methods is to find a table satisfying the protection level requirements and minimizing a loss of information function. In "A Unified Mathematical Programming Framework for Different Statistical Disclosure Limitation Methods," J. J. Salazar-González uses integer programming to compare the two most widely used methodologies: cell suppression and controlled rounding. He also proposes two new methodologies, partial cell suppression and partial controlled rounding, which are the continuous linear programming versions of the two standard methods, thereby enabling efficient solution algorithms.

War at Sea in the Missile Age

If you've ever played games such as Battleship™ or read about the naval battles of the Falklands War, you know that uncertainty (randomness) often has a major impact on the results of the conflict. By contrast, the mathematical models used to describe naval battles are often deterministic in nature and so ignore any uncertainty about the outcome. In "A Stochastic Salvo Model for Naval Surface Combat," M. J. Armstrong incorporates the inherent unpredictability of combat into a model of naval missile warfare that is simple enough to implement in spreadsheet software. He does this in a way that is reminiscent of the World War II roots of operations research: he adapts some techniques from civilian science (in this case, inventory theory) to produce a model that is useful to military decision makers. The resulting analysis has implications not only for naval tacticians, but also for policy makers who might be tempted to commit their citizen-sailors to the risks of an impending conflict.

Power Control in Wireless Communication

While point-to-point wireless communication has made significant advances over the last few years, energy is still a constraining factor in most wireless communication systems. In particular, a key concern in most wireless systems is energy-efficient packet transmissions. In "Dynamic Power Control in a Wireless Static Channel Subject to a Quality-of-Service Constraint," B. Ata studies congestion-dependent rate control, and uses dynamic programming techniques to derive an explicit formula for the optimal transmission rate as a function of the backlog in the system.

Modeling and Analysis of Automated Agile Serial Production Systems

Revolutionary changes in information technology, globalization of markets, and competition have radically altered manufacturing systems over the past two decades. Under pressure to continually improve the price, variety, and responsiveness they offer to customers, firms have increasingly moved toward highly flexible production facilities making use of *automated flexible machinery* and *cross-trained workers*. While there is ample evidence that U.S. manufacturers are adopting such automated agile production systems, there has been little research on these systems. In "Serial Agile Production Systems with Automation," W. J. Hopp, S. M. R. Iravani, and B. Shou try to fill this gap by modeling automated agile serial production systems and proposing a set of planning, design, and control principles. Their results show that the capacity of production lines with automatic machines and cross-trained workers can be significantly lower than the rate of their bottlenecks. They also show that automating a manual machine can have a dramatic effect on the average Work In Progress (WIP) level, provided that labor is the system bottleneck. Once a machine becomes the bottleneck, the benefits from further automation are dramatically reduced. Finally, they find that automation is more effective when placed toward the end of the line rather than toward the front.

Alternate Loss Functions for Selection Procedures

Ranking and selection procedures are commonly used in simulation, agricultural, and medical applications to select the best of a finite set of alternatives (simulated supply chain designs, alternate crop treatments, different medical interventions). Classical procedures based on worst-case frequentist statistics guarantee a user-specified probability of correct selection. When the performance measure of each system is economic value, however, the expected opportunity cost of a potentially incorrect selection makes more sense than the probability of incorrect selection. In "Selection Procedures with Frequentist Expected Opportunity Cost Bounds," S. E. Chick and Y. Wu provide a guaranteed upper bound for the expected opportunity cost of selection procedures. The problem was motivated by the observation that existing frequentist procedures require an end user to specify two parameters (a probability of correct selection, and a minimal difference in performance worth detecting) rather than the one parameter that makes more sense to the bottom line (expected opportunity cost).

Finding an Expected Minimum Cost Configuration

Designing a distribution or communication system that connects users in the most economical way is a fundamental optimization problem faced by decision makers. When the system is defined by a network configuration, the simplest such model requires finding a minimum spanning tree in the associated network with known edge weights. This classic network optimization problem has applications in areas as diverse as manufacturing, image processing, and numerical taxonomy. Unfortunately, the assumption of deterministic edge weights is not always realistic. In "Bounding Distributions for the Weight of a Minimum Spanning Tree in Stochastic Networks," K. R. Hutson and D. R. Shier describe an approach for approximating the distribution of the minimum spanning tree weight when the edge weights have discrete probability distributions. This development subsumes previous approaches in the literature, and it provides easily computed upper and lower bounds on the average minimum spanning tree weight. Computational results indicate that these new bounds are quite promising.