A Random Walk Down Hearst Avenue

Energy and Market Engineering Symposium in Honor of Shmuel Oren

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Uncertainty and the Oren Triangle

- Stochastic equilibria
- Economics
- Operations research
- Power systems
- Stochastic unit commitment and priority service
- Decomposition and HPC
Decision-Making under Uncertainty

“Treat my students like I treat my children.”
- Shmuel Oren
Intro to Decision Trees: Decision Nodes

• Decision trees are the basic building blocks of *sequential decision making under uncertainty*

• **Decision nodes** represent stages at which an agent needs to decide on an action

• The action influences the agents’ future states

• Decision nodes are indicated with boxes
Intro to Decision Trees: Outcome Nodes

- **Outcome nodes** represent stages at which nature reveals uncertainty.
- The uncertainty may depend on the past decisions.
- Decision nodes are indicated with circles.
- Each outcome has an associated probability.
Intro to Decision Trees: Payoffs

- **Payoffs** represent rewards that an agent collects as a function of past decisions and uncertainty realizations.
- Payoffs are typically represented with continuous data such as:
  - numerical values, or
  - emojis
Intro to Decision Trees: Optimal Decisions

• **Optimal decisions** are determined by back-tracking our options and computing their expected payoff

• We select the decision with the greatest expected payoff

• The optimal choice between MIT and Berkeley is clearly and always Berkeley. Go Bears.
Follow the Love

Acknowledgments

First and above all I wish to acknowledge the nurturing of my adviser, Professor Shmuel Oren. My decision to study at Berkeley was preceded by four agonizing weeks of comparing on the competing offers that I was fortunate to receive. Ultimately, one motto that I abide to to this day guided my decision: follow the love. After four weeks of analyzing facts and figures, the deadlock was broken by my instinctive reaction to the warmth that emanated from my future adviser during our initial communications following my acceptance at Berkeley. Shmuel Oren is an exemplary academic, a deeply experienced specialist in the field of electricity, but most importantly he adheres to principles that I admire. During one of our off-topic discussions, he put it in the following words: "I treat my students like I treat my children". Apart from his sweeping influence in my reasoning and knowledge about the field of electricity and operations research, Shmuel has been exactly this to me during my five years at Berkeley: a fatherly figure.
Power Systems: Stochastic Unit Commitment and Priority Service

“Economists are good at finding problems and bad at proposing solutions.”

- Shmuel Oren
Stochastic Unit Commitment

- **Original motivation:** quantify benefits of demand response in reducing reserve requirements
- **Eventually:** operational tool for day-ahead residual unit commitment
Insights

- Deterministic unit commitment underestimates the cost of fast unit activations
- Stochastic UC pays off especially in the presence of transmission constraints
Hierarchical Organization of Future Systems

Uncertainty

Layer $l - 1$

Layer $l + 1$

$\Omega = \Omega_{\text{local}} \times \Omega_{\text{interface}}$

Day-ahead planning: distributed

Action

Layer $l - 1$

Layer $l$

Layer $l + 1$

Real-time dispatch: hierarchical
Priority Service Pricing

• The *residential sector* is a key part of the solution
• Oren-Chao-Wilson priority service pricing problem can be cast as a Stackelberg equilibrium and *integrated* with *unit commitment models*
• Individual households can be controlled by *energy routers* trained by *reinforcement learning*
Operations Research: Decomposition and HPC

“You look like you haven’t slept in a week.”

- Shmuel Oren
Decomposition

Dual multiplier update

Second-stage subproblems $P_{2_s}$

First-stage subproblem $P_1$

Second-stage feasibility runs $E_{D_s}$

Monte Carlo economic dispatch $E_{D_c}$

$u_{gst}^*$ $v_{gst}^*$ $\mu_{gst}$ $v_{gst}$

$1$ $2$ $\cdots$ $N_s$

$1$ $2$ $\cdots$ $N_s$

$1$ $2$ $\cdots$ $N_c$
High Performance Computing

• Asynchronous dual decomposition can improve parallel computation performance tremendously
• Today, we can solve SUC with $O(100)$ scenarios on real systems in $O(\text{minutes})$
Economics: Stochastic Equilibria

“We need to talk.”

- Shmuel Oren
Scarcity Pricing

• The *missing money problem* has recently hit Belgium hard, winter 2014-2015 and winter 2018-2019 have been *very tight* for Belgium

• **Scarcity pricing** (a.k.a. ORDC) is a market design that mitigates the missing money problem by introducing a real-time market for reserve capacity that values reserve based on LOLP calculations

• Belgian system operator (ELIA) recently published *parallel runs* on the impact of scarcity pricing in the Belgian market for 2017

• The Belgian regulatory authority (CREG) has commissioned a study on the **design** of a scarcity pricing mechanism
Insights

• The model can be used in order to capture the back-propagation of reserve capacity prices to forward markets

• Recommendation to Belgian regulatory authority
  • Set real-time market for reserve capacity in place
  • Virtual trading and day-ahead co-optimization of energy and reserves less important
Open Challenges

• Difficult non-linear complementarity problems
• Cast equilibrium as variational inequality (VI)
• Isolate the part of the VI that corresponds to a stochastic program
• Apply splitting algorithms to the operators that correspond to (i) the stochastic program, and (ii) the remainder:
  • Forward-backward splitting
  • Douglas-Rachford splitting
  • Tikhonov regularization
Thank You Shmuel for the Incredible Ride!