The Incentive Auction: A Practical Success Story for Economic and Policy Impact of AI

Kevin Leyton-Brown

Computer Science Department University of British Columbia

&

Auctionomics, Inc.



Auctionomics

The One Hundred Year Study on Al

http://ai100.stanford.edu

- A long-term investigation of AI and its influences on people, their communities, and society
 - based at Stanford University, endowed and initiated 2014
- Every 5 years, a study panel assesses current state of AI:
 - reviews recent progress
 - envisions the potential advances that lie ahead
 - describes the technical and societal challenges and opportunities these advances will raise
- After a year of study, first report just released
 - Focus: likely influences of AI in a typical North American city by 2030
 - Domains: transportation; service robots; healthcare; education; low-resource communities; public safety and security; employment and workplace; entertainment

Recent, enormous increases in compute power

Approaches that might have seemed crazy in 2000 can make a lot of sense in 2016...



Sources: Intel; press reports; Bob Colwell; Linley Group; IB Consulting; The Economist *Maximum safe power consumption

Deep Optimization

Machine learning

- Classical approach
 - Features based on expert insight
 - Model family selected by hand
 - Manual tuning of hyperparameters

Deep learning

- Very highly parameterized models, using expert knowledge to identify appropriate invariances and model biases (e.g., convolutional structure)
 - "deep": many layers of nodes, each depending on the last
- Use lots of data (plus "dropout" regularization) to avoid overfitting
- Computationally intensive search replaces human design

Discrete Optimization

Classical approach

- Expert designs a heuristic algorithm
- Iteratively conducts small experiments to improve the design

Deep optimization

- Very highly parameterized algorithms express a combinatorial space of heuristic design choices that make sense to an expert
 - "deep": many layers of parameters, each depending on the last
- Use lots of data to characterize the distribution of interest
- Computationally intensive search replaces human design

FCC's "Incentive Auction"

🔁 USATC	Search				Q			
E MONEY TECH TRA	AVEL OPINION	<i>⇔</i> ‴	CROSSWORDS	ELECTIONS 2016	INVESTIGATIONS	VIDEO	STOCKS	MORE
FCC's com billion	n <mark>pl</mark> ex ind	centiv	e auct	ion cou	ld net m	ore t	han	\$30
Mike Snider, USA TO	DAY 7.19 a.m. ED	T March 30, 201	6					
Image: Section of the section of th			Source of the sector of the					
(Photo: MANDEL NGAN, AFP/Gelty Images)	TV broadc official the	asters by Tue ir intentions to	esday night mus	t have made C's opening				100
price for the rights to the s the agency knows how me auction," then, in a few me auction" in which compani spectrum in each of 400-p	spectrum they curre uch spectrum can t onths, the FCC will les such as AT&T a plus localities.	ently use for o be made avail open up the and Verizon c	ligital TV broadd lable in this "rev bidding in the "fe an bid onthe rea	asts. Once erse orward illocated		ORE STORIES	\$	Ŷ

The FCC's "Incentive Auction"

- Reverse (descending-price) auction for broadcasters
 - prices offered for stations decreases while supply exceeds demand
- Forward (ascending-price) auction for telecom firms
 - prices in each region increase while demand exceeds supply
- When auctions terminate, ensure revenue target is met
 - if not, grow the size of the reduced band (i.e., clear less spectrum); auctions continue



Feasibility Testing via MIP Encoding



We Applied Deep Optimization

- Used advanced "Bayesian optimization" methods to learn an algorithm adapted to:
 - data that arose under (a wide range of) simulations of the actual auction mechanism in use
 - the actual United States television constraint graph
- Hypothesis space for this learning procedure:
 - many open-source SAT solvers
 - various problem-specific heuristics
 - a novel caching scheme
- Ran experiments on a dedicated computer cluster for roughly a year
- Ultimately built a portfolio of eight algorithms

SATFC: A Deep Optimization Solver



How Well Does The Incentive Auction Work?



Conclusions

- Likely impact of AI by 2030, and policy implications: AI100 study panel report at <u>http://ai100.stanford.edu</u>
- **Deep Optimization:** leverage massive computational resources to "learn" domain-specific algorithms
- Incentive Auction: a high-stakes application; the deep optimization approach is yielding tangible social benefits

