The Challenges that Society Brings to Engineering Designs...

...and the games they play...

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(ECE 149 - Game Theory)
Field of Dreams...

if you build it, they will come...
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Field of Dreams...

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Field of Dreams...

if you build it, they will come...

but will they use it efficiently?
Goal: Determine “most” beautiful contestant

Experiment: Beauty contest
Experiment: Beauty contest

Goal: Determine “most” beautiful contestant

Game Theory = Study/Influence Social Behavior
Game Theory = Analysis/Influence Social Behavior

microscopic interactions → macroscopic phenomena
Game Theory = Analysis/Influence Social Behavior

microscopic interactions → macroscopic phenomena

decision makers
choices
conditional preferences

“game”
Game theory: Broader view

Game Theory = Analysis/Influence Social Behavior

microscopic interactions → macroscopic phenomena

decision makers
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“game”

DMs = white/black
choices = moves
preferences = win
Game theory: Broader view

Game Theory = Analysis/Influence Social Behavior

microscopic interactions $\rightarrow$ macroscopic phenomena

decision makers
choices
conditional preferences

“game”

DMs = drivers
choices = routes
preferences = minimize time
Game theory: Broader view

Game Theory = Analysis/Influence Social Behavior

microscopic interactions → macroscopic phenomena

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“game”

Social Norms?

QWERTY vs DVORAK

traditional keyboard
optimized keyboard
Game Theory = Analysis/Influence Social Behavior

Microscopic interactions $\rightarrow$ macroscopic phenomena

<table>
<thead>
<tr>
<th>decision makers</th>
<th>choices</th>
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John Nash
(Nobel Prize 1994)
Game Theory = Analysis/Influence Social Behavior

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John Nash
(Nobel Prize 1994)

eBay

A Beautiful Mind
Beautiful mind

microscopic interactions \(\uparrow\) macroscopic phenomena
\(\downarrow\) decision makers
choices
preferences

emergent behavior? efficient? coordination?
emergent behavior?
efficient?
coordination?
Nash equilibrium

“Nash equilibrium”
Emergent behavior = Conditionally optimal choices
(i.e., best choice given choices of other DMs)

John Nash
(Nobel Prize 1994)
“Nash equilibrium”

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John Nash
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Grand Banks Fisheries

- 1950s: Endless supply of cod fish
- 1960-1970: Advancements in fishing technology
- 1990s: Collapse due to low cod populations

emergent behavior? efficient? coordination?
Tragedy of the commons

Grand Banks Fisheries

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Social Norms

society could adopt inferior convention

emergent behavior? efficient? coordination?
Tragedy of the commons

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Social Norms

Transportation Systems

uninfluenced traffic
(can be suboptimal
(tolls not necessarily for $)

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Not Efficient Behavior!

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Not Efficient Behavior!

efficient? coordination?
There are many mechanisms you are exposed to on a daily basis that are in place to influence your behavior.

- eBay (auctions)
- United (overbooked flights)
- Boulder Valley School District (school assignments)
Incentivizing behavior

There are many mechanisms you are exposed to on a daily basis that are in place to influence your behavior.

*success story*

- eBay (auctions)
- United (overbooked flights)
- Boulder Valley School District (school assignments)
Auctions

choices = how much $ to bid
preference = win tickets at lowest possible cost
objective = optimize surplus or revenue (uncertainty)

system choice = report? who wins? payments?
Auctions

BIDS

100  80

150  70

250  175
Auctions

BIDS

100

80

150

70

175

250

WINNER
WINNER

PAYS: $80 (second highest price)
Auctions

Why not have Ned pay his bid $175?
Incentivizing behavior

There are many mechanisms you are exposed to on a daily basis that are in place to influence your behavior. One such mechanism is the eBay auction system, which is a success story:

- (i) optimizes social surplus
- (ii) optimal to bid true value

Incentivizing behavior

There are many mechanisms you are exposed to on a daily basis that are in place to influence your behavior.

(i) not efficient for BVSD
(ii) not efficient for parents
Incentivizing behavior

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Incentivizing behavior

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United Airlines

United’s way of bumping ‘is very inefficient,’ says auction expert

By Ethan Wolff-Mann

m.yahoo.com — United’s way of bumping ‘is very inefficient,’ says auction expert Yahoo Finance Wednesday, April 12, 2017 Ethan Wolff-Mann With a proper auction, there is no such thing as involuntary bumping. Source: APAfter a viral video emerged this week of United Airlines (UAL) dragging a paying customer off a plane, some outraged consumers attacked the airline industry’s practice of overbooking. Not all airlines overbook, with JetBlue (JBLU) being a notable exception.

3 MONTHS AGO  f  |  in  |  twitter  | Who shared?
microscopic interactions \[\uparrow\] decision makers \[\downarrow\] choices preferences

\[\uparrow\] emergent behavior? efficient? coordination?

macroscopic phenomena \[\downarrow\]
emergent behavior?

efficient?

coordination?

simplifying assumptions
transportation network
driver behavior models

emergent behavior?

efficient?

coordination?
simplifying assumptions
transportation network
driver behavior models

\[ c_h(x) = x \]

\[ c_l(x) = 1 \]

system demand
unit flow of traffic
congestion functions
simplifying assumptions
transportation network
driver behavior models

\[ c_h(1) = 1 \]

\[ c_h(x) = x \]

\[ c_l(x) = 1 \]
simplifying assumptions
transportation network
driver behavior models

\[ c_h(0.5) = 0.5 \]
\[ c_h(x) = x \]

system demand

\[ c_l(x) = 1 \]
\[ c_l(0.5) = 1 \]
simplifying assumptions
transportation network
driver behavior models

drivers seek to minimize
own experienced congestion

unit flow of traffic

\[ c_h(0.5) = 0.5 \]
\[ c_h(x) = x \]

system demand

\[ c_l(x) = 1 \]
\[ c_l(0.5) = 1 \]
Motivation:

- Uninfluenced systems often exhibit poor system behavior
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system optimal outcome vs. self-interested outcome
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system optimal outcome vs. self-interested outcome
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\[
\begin{align*}
    c_h(x) &= x \\
    c_l(x) &= 1
\end{align*}
\]

system optimal outcome vs. self-interested outcome
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\[ c_h(x) = x \]
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system optimal outcome vs. self-interested outcome

\[ 3/4 \]
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System optimal outcome vs. self-interested outcome

3/4 vs. 1
Motivation:
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Pigou’s network

\[ c_h(x) = x \]
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System optimal outcome vs. self-interested outcome

Self-interested outcome 33% worse than optimal outcome
Motivation:

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Braess Paradox

original network vs. original network + extra edge
Motivation:

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\[ c(x) = x \quad c(x) = 1 \]

original network vs. original network + extra edge

1.5

Braess Paradox
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Original network vs. original network + extra edge

\[ c(x) = x \]
\[ c(x) = 1 \]
\[ c(x) = 1 \]
\[ c(x) = x \]

\[ \frac{1}{2} \]

Original network

\[ c(x) = x \]
\[ c(x) = 1 \]
\[ c(x) = 0 \]
\[ c(x) = x \]

\[ \frac{1}{2} \]

Original network + extra edge

\[ \frac{1}{2} \]

\[ 1 \]

\[ 1.5 \]

\[ 2 \]
Motivation:

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original network vs. original network + extra edge

additional resources resulted in 33% worse system performance
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Research Thrust: Develop methodologies for robust social coordination to improve system-level performance (taxes)
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Research Thrust: Develop methodologies for robust social coordination to improve system-level performance (taxes)

simplified models provide us insight to challenges and opportunities in realistic setting
**Motivation:**
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**Research Thrust:** Develop methodologies for robust social coordination to improve system-level performance (taxes)

Identify salient features of robust coordinating mechanisms
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Take away points:

- Ensuring “systems” utilized efficiently is challenging
- Natural choice need not be good choice
- Deriving mechanism requires thorough theoretical analysis
- Game theory is instrumental in the design of good mechanisms
- Engineers need awareness of Game Theory to design such systems

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(avoid situations like this)
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i never realized i was a player in a game

Thank You