ORIE 6170: Engineering Societal Systems

Lecture 3: Engineering Economics & Wicked Problems

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Announcements

Paper discussion signup + instructions out

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Next time: 2 Papers for which we need discussants

Residency matching and Economists as Engineers

Roth 2002

The market failure

Similar *unraveling* to what we saw above:

- Hospitals (especially less glamorous ones) started hiring future residents earlier and earlier during medical school (~1940s)
- In response, other hospitals also started hiring earlier. The market unraveling, such that students were being offered residency positions before they knew what they wanted to do (this is clearly bad)
- Many other labor markets have seen the same unraveling [Roth and Xing (1994)]

Initial solution desiderata

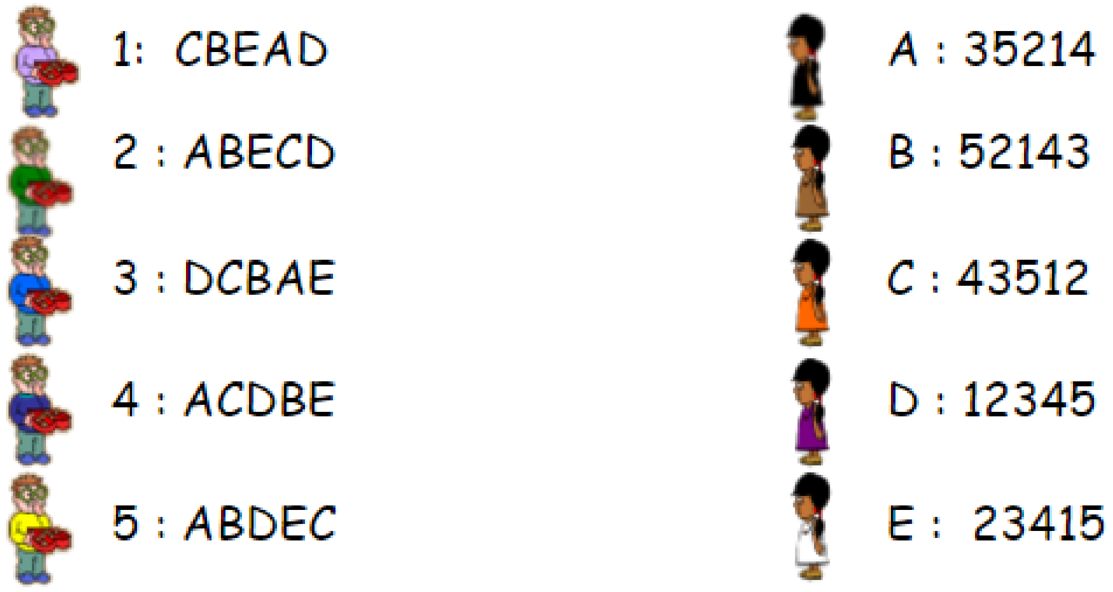
- In 1940s, a few attempts to fix the problem that didn't work well
  - People were getting residency offers 2 years before graduating medical school
- By 1951, a *centralized algorithm* would match doctors and hospitals

What are participants *action spaces*/what is the system *lever*?

- *Doctors* and *hospitals* each give ranked lists of the other side
  - Anyone can lie about their true preferences
- [Algorithm does the matching; assigns each doctor to a hospital]
- *Doctors* and *hospitals* can break their match
  - Suppose algorithm produces matches (A, X) and (B, Y). But Doctor A likes Y>X, and hospital Y likes A>B.
  - Then, (A,Y) can defect from the system and instead match with each other

Initial solution: Gale-Shapley in 1 slide

- Desiderata:
    - Doctors and Hospitals each submit *truthful* ranked lists
    - After the algorithm produces its solution, there is no “blocking pair”: there exists no (A,Y) that would want to leave their assigned partner for each other
- How it works:



Summary of theory of Gale-Shapley

- Theorem: A stable matching always exists [No “blocking pairs”]
- Theorem: Gale-Shapley algorithm finds a stable matching
- Theorem: Participants don’t want to lie about their preferences, *but only the “proposing” side.*
- Theorem: In every stable matching, the same participants are left unmatched [rural hospital theorem]

Problem solved? By 1970s, people started complaining again…

- Increase in *couples* in medical schools wanting to match together
- Implementation of algorithm favors hospitals? (Over doctors?)
- Concerns about strategic behavior by doctors

The redesign of the market (1990s)

Favoring doctors over favoring hospitals:

“Simple” change to algorithm: have doctors “propose” instead of hospitals. Rest of theoretical results hold. (And now, it’s strategy-proof for doctors!).

Couples: harder case -- Stable matching may not exist

BUT, some hope:

- Computational simulations suggest that in practice stable matchings almost always exist
- Follow up theory (e.g., Nguyen & Vohra 2018): “for any student preferences, we show that each instance of a matching problem has a "nearby" instance with a stable matching”

Problem solved forever?

Theory differs from practice in many ways

- Empirically, many doctors still mis-report their preferences. Why?
- The algorithm assumes people *know everything* about the other side, and can rank as many as they want
  - In practice, this is not true: you must *interview* at a school to even have a chance. So, if you only interview at top schools and don't get any…
  - Opposite problem: what if the same top 10 doctors interview everywhere (50 hospitals, each with 1 position)?
    - Evidence that this happened last few years due to Zoom interviewing
    - Recent proposal to have a centralized matching system for interviews: Explaining a Potential Interview Match for Graduate Medical Education | Journal of Graduate Medical Education (allenpress.com)
- Problems more severe in other places stable matching is used: e.g., school matching!

Lessons from residency matching

- Systems can fail due to seemingly minor incentives issues (causes bad equilibria)
- Designing even a limited system is hard and often politically tense
- Interplay between theory, empirical analysis, and simulation
    - "It turned out that the simple theory offered a surprisingly good guide to the design, and approximated the properties of the large, complex markets fairly well. Field and laboratory data showed that the static idea of stability went a long way towards predicting which kinds of clearinghouse could halt the dynamics of unraveling. And computation showed that many of the departures from the simple theory were small, and that some of the most severe problems that the counterexamples anticipated, such as the possibility that no stable matching would exist, were rare in large markets. Computation also revealed that large markets could achieve even nicer incentive properties than anticipated by the simple theory."
- Objective functions matter! (Doctor vs hospital optimal)
- People often don't behave "optimally," but that doesn't make theory useless
- Even if one component of the system is provably optimal, surrounding components (here, interview process) might undo benefits

Some nice quotes from Al Roth (2002)

- The largest lesson in all this is that design is important because markets don't always grow like weeds—some of them are hothouse orchids. Time and place have to be established, related goods need to be assembled, or related markets linked so that complementarities can be handled, incentive problems have to be overcome, etc. If game theory is going to be as important a part of design economics as it is a part of economic theory, we'll have to develop tools not just to develop conceptual insights from simple models, but also to understand how to deal with these complications of real markets.

- In the long term, the real test of our success will be not merely how well we understand the general principles that govern economic interactions, but how well we can bring this knowledge to bear on practical questions of microeconomic engineering. Just as chemical engineers are called upon not merely to understand the principles that govern chemical plants, but to design them, and just as physicians aim not merely to understand the biological causes of disease, but their treatment and prevention, a measure of the success of microeconomics will be the extent to which it becomes the source of practical advice, solidly grounded in well tested theory, on designing the institutions through which we interact with one another

So what has changed since 2002?

- Rise of online marketplaces (and more generally, computational systems) has made the type of work he described ubiquitous
- What's difference? These applications are far "messier"
  - Faster (many times a second, as opposed to once a year)
  - Many complexities; not a 'closed' system. (in ride-hailing, pricing affects matching affects wages affects long term driver capacity…)
- The field is more mature, new methods, incorporation of data science
- We're going to focus on these more "modern" applications and especially as it interfaces with prediction
- Critiques of approach, as enters more sensitive areas

Wicked Problems

Dilemmas in a General Theory of PlanningAuthor(s)

Horst W. J. Rittel and Melvin M. Webber
Jun., 1973

By now we are all beginning to realize that one of the most intractable problems is that of defining problems (of knowing what distinguishes an observed condition from a desired condition) and of locating problems (finding where in the complex causal networks the trouble really lies). In turn, and equally intractable, is the problem of identifying the actions that might effectively narrow the gap between what-is and what-ought-to-be. As we seek to improve the effectiveness of actions in pursuit of valued outcomes, as system boundaries get stretched, and as we become more sophisticated about the complex workings of open societal systems, it becomes evermore difficult to make the planning idea operational.

The methods of Operations Research play a prominent role in the systems-approach of the first generation; they become operational, how-ever, only after the most important decisions have already been made, i.e. after the problem has already been tamed.

Characteristics of wicked problems

- There is no definitive formula for a wicked problem.
- Wicked problems have no stopping rule, as in there’s no way to know your solution is final.
- Solutions to wicked problems are not true-or-false; they can only be good-or-bad.
- There is no immediate test of a solution to a wicked problem.
- Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial-and-error, every attempt counts significantly.
- Wicked problems do not have a set number of potential solutions.
- Every wicked problem is essentially unique.
- Every wicked problem can be considered a symptom of another problem.
- There is always more than one explanation for a wicked problem because the explanations vary greatly depending on the individual perspective.
- Planners/designers have no right to be wrong and must be fully responsible for their actions.

Cross-cutting methodology in this course

Questions you need to answer

- What is your [the system's] *lever?*
- What is your *objective function?*
- How do people *react* to your lever?
  - What are people's *preferences?*
  - What are people's *strategy spaces?*
- How do people affect *each other?*
- What is the information space?
  - What is being predicted? What do you care about?
  - What do you know? What data do you have?
  - What do people know?
  - How do you acquire more information?
  - Will this change over time?
- *What happens when your system is wrong?*
- *What is the "wicked problems" critique of the work?*

Common tasks

- Understand your domain
- Write a model for the ?s on the left
- Think about "equilibria"
- Estimate preferences from historical data
- Simulate counter-factual worlds
- Experiment/Pseudo-experiment
- Evaluate as close to "real world" as possible
- Deploy a system

Methods used

- Applied modeling/stochastics
- Game theory/mechanism design
- Optimization, Algorithms
- Machine learning/statistics/data science
- Online learning/decision-making
- Experimentation
- Qualitative methods

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