Logistics

- No Class next Thursday
  - I’m giving a talk that conflicts with our class time
  - Use this time to finalize your project milestone 1!

- Project milestone 1
  - Due Oct 14 (Next Friday)
  - Initial literature survey (know what other works are out there)
  - A plan on what you want to do for the remaining of the semester
    - Formalize your research question and approaches, e.g.,
      - Theory/simulation project: formalize your models
      - Data-analysis project: figure out where and how to get data and what you plan to do with it
      - Experiment/application project: have a prototype design and an evaluation plan
    - Include a timeline (weekly or biweekly) on what you plan to do
      - Nov 1: Midterm project pitch and discussion
      - Nov 4: Milestone 2 report

Logistics

- Assignment 3:
  - Due: ~~Oct 13 (Wednesday)~~
  - Extended to Oct 17 (Monday) in observance of fall break

Logistics: Peer Reviews

- For each of the student presentations, please fill in the peer review form.
  - The link to the form will be posted on the course website before the lecture

Sep 27	Incentive Design: Financial Incentives Presenter: Daisy and Xinyi [Presentation Slides] [Additional Slides] Peer Review Form

- Please try to submit the form **by 6pm**.
- Please be polite. List positives and points to improve. Be constructive.
- The feedback will be anonymous to the presenters but not anonymous to CJ.

Switch Over to Presenters

Lecture 11
Additional Discussion for DARPA Network Challenge: Incentives and Learning in Networks

Instructor: Chien-Ju (CJ) Ho

The Small-World Experiment [Stanley Milgram, 1967]

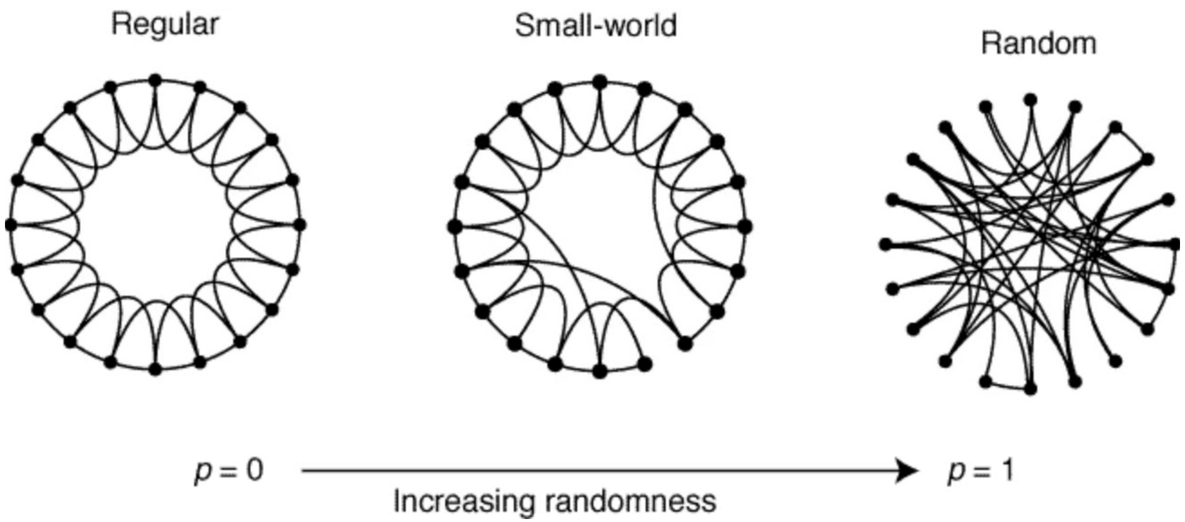
[The figure is from Wikipedia]

- How many hops does it take to deliver a mail from a person in Nebraska/Kansas to a person in Massachusetts?
- A person can only pass the mail to someone she/he knows in a first-name basis.
- Average: Around 5.5~6 hops
  - Six degrees of separation

There are criticisms on the methodology, but the results are still very impressive

Small-World Networks [Watts and Strogatz, Nature 1998]

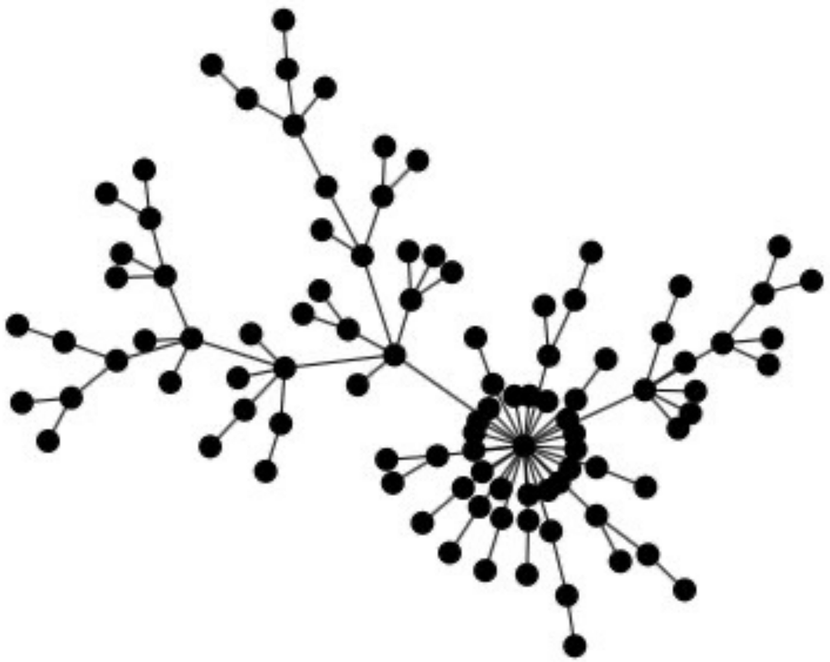
- Two characteristics
  - People form "cliques" (my friends are usually my friends' friends)
  - There are some random links



- "One of the models" that explain the small world phenomenon

Another Social Network Model

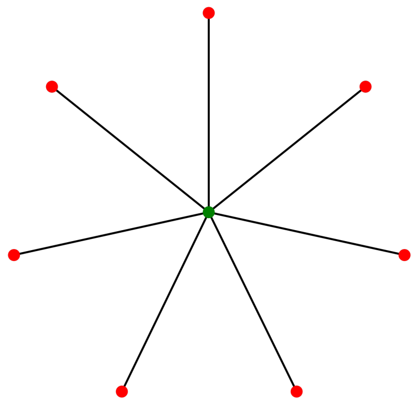
- Preferential Attachments (Barabási–Albert Model)
  - People join the network one by one
  - Attach (form edges) to existing members
  - Attach probability is proportional to # edges



- Explains the rich-gets-richer effect

Friendship Paradox [Scott L. Feld. 1991]

- On average, do your friends have more friends than you have?
  - Yes, if we take the average over everyone in the network.



Average # friends: $\frac{7*1+7}{8} = 1.75$

Average # friends a person's friends have: $\frac{7*7+1}{8} = 6.25$

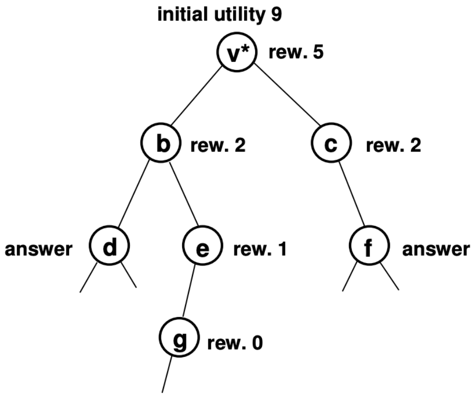
- Local observations could be distorted by the network structure
  - One's friends are happier, wealthier, more popular…

Utilizing the Power of Networks

- Given we can reach most people in a small number of hops, can we utilize the people in networks to help with tasks.
- Not that trivial
  - A replication of the small world experiment using emails has faced a high-level of drop-out rate since people are not motivated in attending.
- Need proper incentives:
  - See more in the seminal paper of query incentive networks

Query Incentive Networks [Kleinberg and Raghavan, 2005]

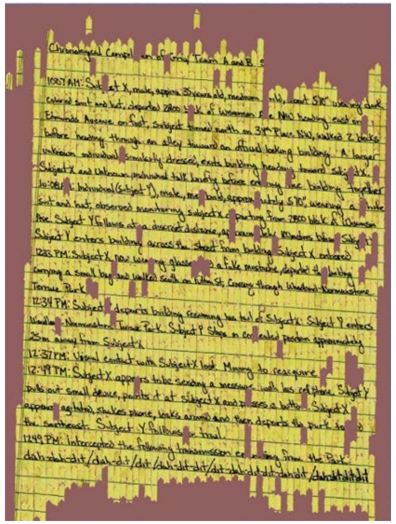
- Formalize the theoretical discussion on incentives in networks

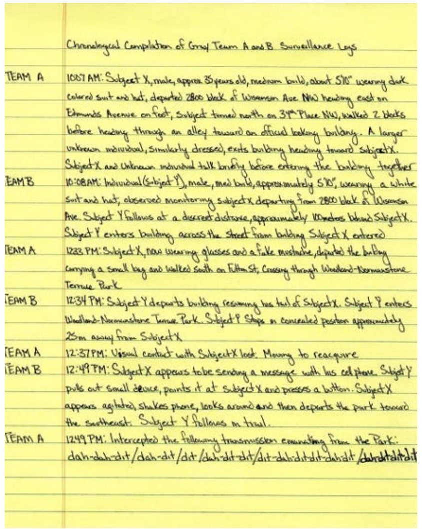


- Successful example: DARPA network challenge

Generalize the Results from DARPA Network Challenge

- DARPA shredder challenge, 2011
  - Goal: Piece together the information in shredded paper

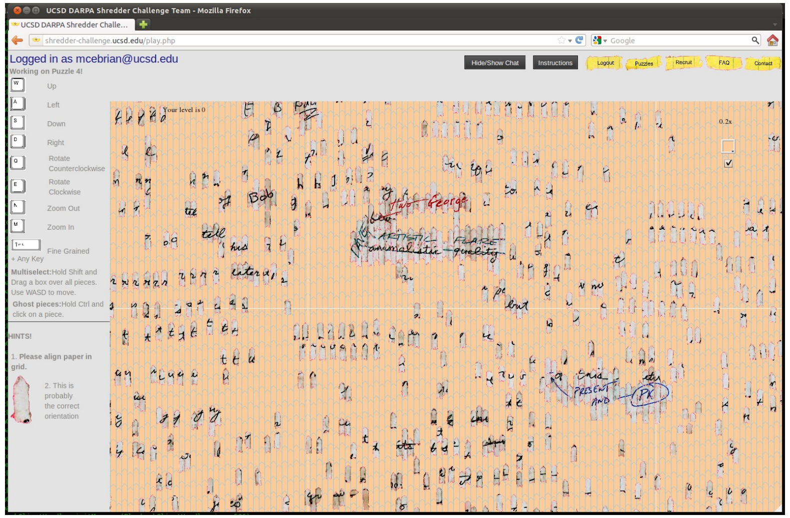




  - First team to complete 5 puzzles win $50,000
  - Duration: October 27, 2011 to December 4, 2011

Generalize the Results from DARPA Network Challenge

- UCSD team tried the same method as MIT team did in network challenge



"However, the crowd was hopeless against a determined attacker. Before the first attack, our progress on the fourth puzzle had combined 39,299 moves by 342 users over more than 38 hours. Destroying all this progress required just 416 moves by one attacker in about an hour."

"creation took 100 times as many moves and about 40 times longer than destruction." [How Crowdsourcing Turned On Me](). Iyad Rahwan.

- Solved 3 (out of 5) puzzles in 5 days
- No progress after that
  - Too many sabotage attempts to ruin their results
  - Designing mechanisms **robust** to adversarial attacks is important but non-trivial

Utilizing the Power of Networks

- Influence maximization [Who should we start to ask questions?]
  - You can send products to K people to try on
  - Assume people who try the product will tell their neighbors with some probability
  - Who should you choose to send the products maximize the expected number of people knowing your product?

Generally a NP-hard question.

There exists efficient approximation algorithms, if you know the network structure.

What if you don't know the network structure?

- Learning and sampling

Utilizing the Power of Networks

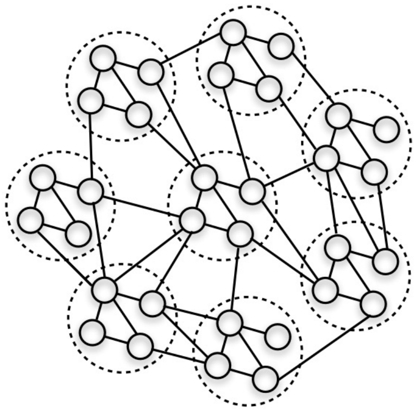
- AI for social good:
  Taking interventions to prevent HIV for homelessness youth [Wilder et al. 2021]

- Procedure
  - Recruit “peer leaders” in drop-in centers
  - Train the leaders and have them help disseminate the information
  - Adapt techniques from influence maximization to maximize the information spread

- Help reduce 31% chance of risky behavior

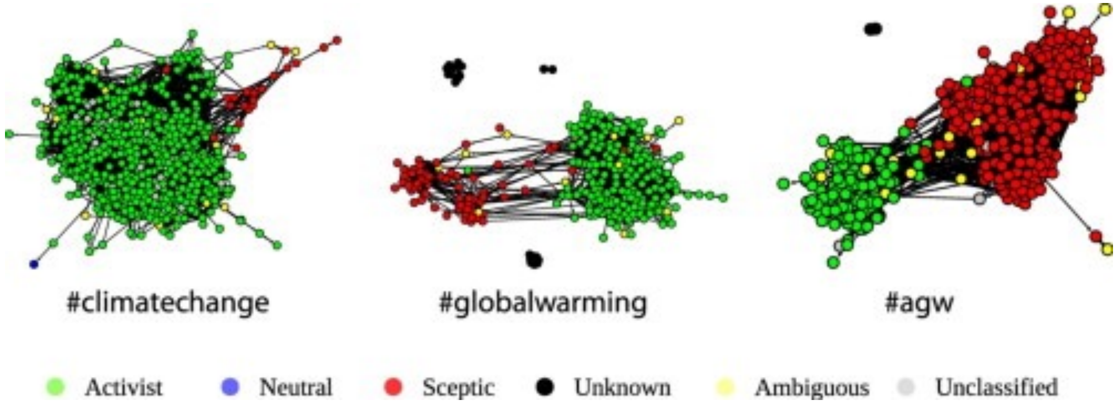
Other Challenges/Opportunities of Networks

- Network could create biases in data collection [Saveski et al. 2017]

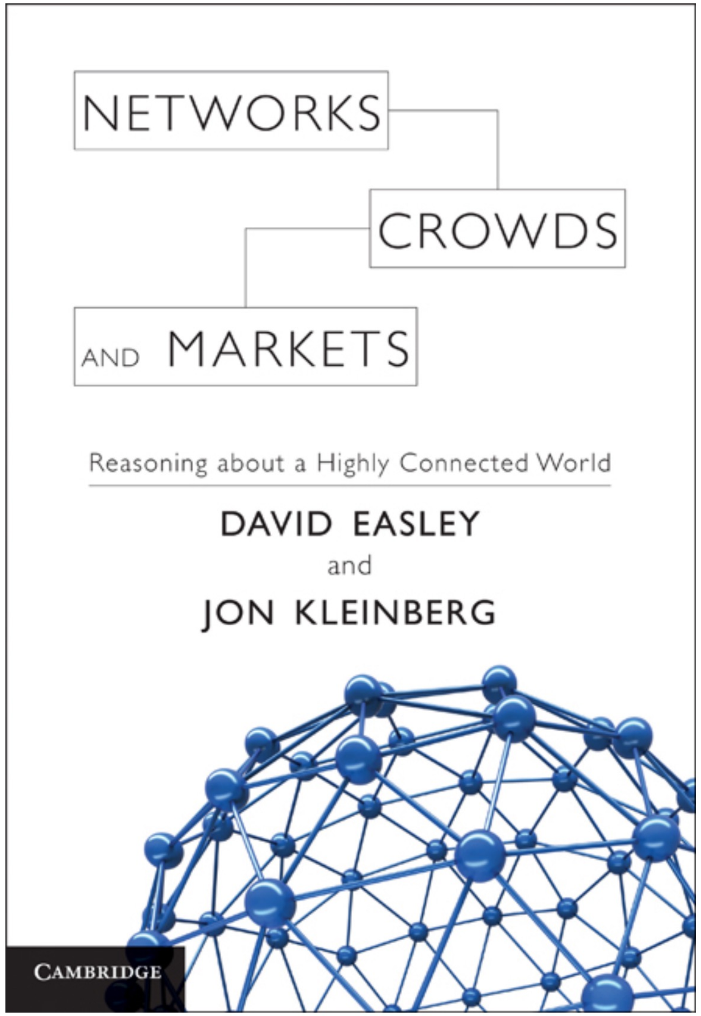


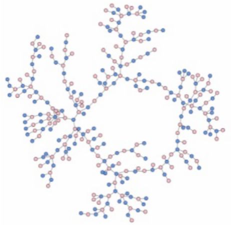
Neighbors might have similar opinions
Break the common “independence” assumption

- Opinion formation: Human opinions might be influenced by networks

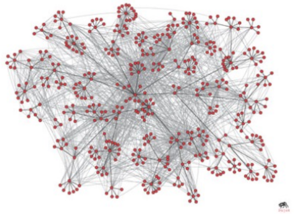


[Williams et al. 2015]



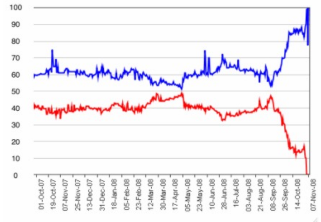


High School Dating
(Bearman, Moody, and Stovel, 2004)
(Image by Mark Newman)



Corporate E-Mail Communication
(Adamic and Adar, 2005)

Trails of Flickr Users
in Manhattan
(Crandall et al. 2009)



Prediction Market for the
2008 U.S. Presidential Election
(Iowa Electonic Markets, 2008)

Networks, Crowds, and Markets:
Reasoning About a Highly Connected World

By David Easley and Jon Kleinberg

https://www.cs.cornell.edu/home/kleinber/networks-book/

Proper Scoring Rules

Incentivizing Truthful Reports About Probabilities

- Example scenarios:
  - Ask a weather forecaster: will it rain tomorrow?
  - Ask a political researcher: will Trump win 2020 election?
  - Ask a Microsoft employer: will the new version of Office be shipped on time?

- Want to obtain forecasts about future events
- How do we make sure we obtain **truthful** reports?

Incentivizing Truthful Reports

- Setting
  - Consider a rational agent with linear utility for cash
  - Suppose there are n mutually exclusive and exhaustive states of the world $\Omega = \{w_1, w_2, \ldots, w_n\}$ (e.g., Sun, Rain, Snow)
  - p_i is the subjective belief of the agent that state w_i will occur
- Question
  - How do we motivate this agent to tell us her beliefs about the likelihood of each state?

Scoring Rules

- A scoring rule rewards an agent $S(\vec{r}, w)$ when her reported distribution is $\vec{r}$ and the realized outcome is w

Scoring Rules

- Let's consider a linear scoring rule

$$S(\vec{r}, w_i) = r_i$$

- If a risk-neutral agent believes the probability for Rain and Sun are

$$\vec{p} = (0.7, 0.3)$$

What report should the agent provide?

Scoring Rules

- A scoring rule rewards an agent $S(\vec{r}, w)$ when her reported distribution is $\vec{r}$ and the realized outcome is w

- A scoring rule is called ***proper*** if the agent maximizes her utility by providing truthful report

$$\vec{p} = \mathrm{argmax}_{\vec{r}} \sum_{i=1}^{n} p_i S(\vec{r}, w_i)$$

- A scoring rule is ***strictly proper*** if honestly reporting is the **unique** maximizer.

Examples of Strictly Proper Scoring Rules

- Quadratic scoring rule (Brier score):

$$S(\vec{r}, w_i) = r_i - \frac{1}{2}\sum_j r_j^2$$

  We can verify this by taking the gradient of the expected payoff

- Affine transformation of the proper scoring rule is still proper.

DEPARTMENT OF COMMERCE
CHARLES SAWYER, Secretary

WEATHER BUREAU
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VERIFICATION OF FORECASTS EXPRESSED IN TERMS OF PROBABILITY

GLENN W. BRIER

U. S. Weather Bureau, Washington, D. C.

[Manuscript received February 10, 1950]

Examples of Strictly Proper Scoring Rules

- Logarithmic scoring rule:

$$S(\vec{r}, w_i) = \log r_i$$

  We can verify this by taking a gradient of the expected payoff

- In logarithmic scoring rule, the score for outcome w_i only depends on the report r_i and not r_j for $j \neq i$

More examples?

- How do we construct a strictly proper scoring rule?

- How many strictly proper scoring rules are there?

Characterization of Proper Scoring Rules

- Connections between convex functions and proper scoring rules.

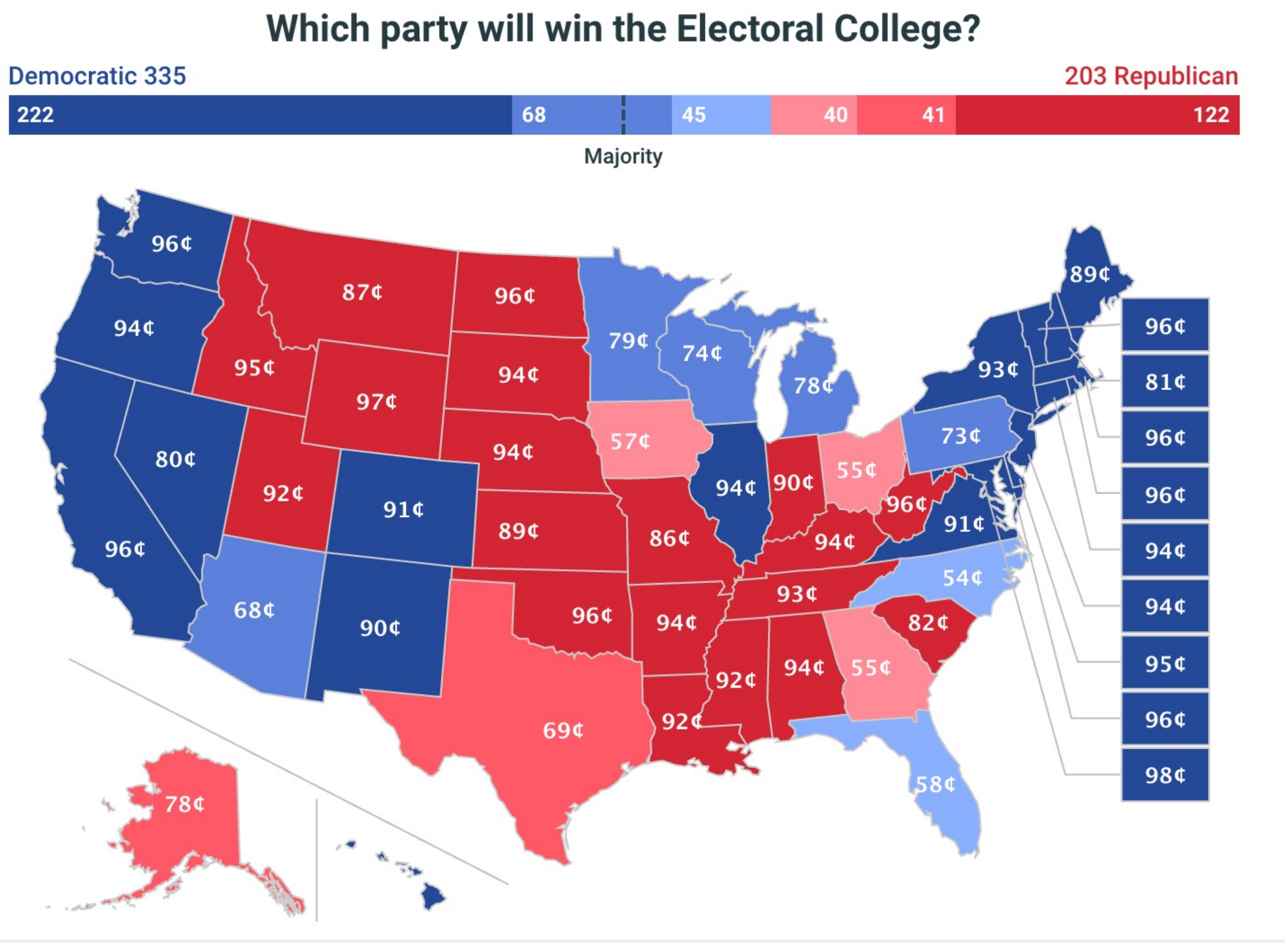
- A scoring rule $S(\vec{r}, w_i)$ is (strictly) proper if and only if

$$S(\vec{r}, w_i) = G(\vec{r}) - \sum_{j \neq i} G_j'(\vec{r}) p_j + G_i'(\vec{r})$$

where $G(\vec{r})$ is a (strictly) convex function, $G'(\vec{r})$ is a subgradient of G at $\vec{r}$, and $G_i'(\vec{r})$ is its i-th component.

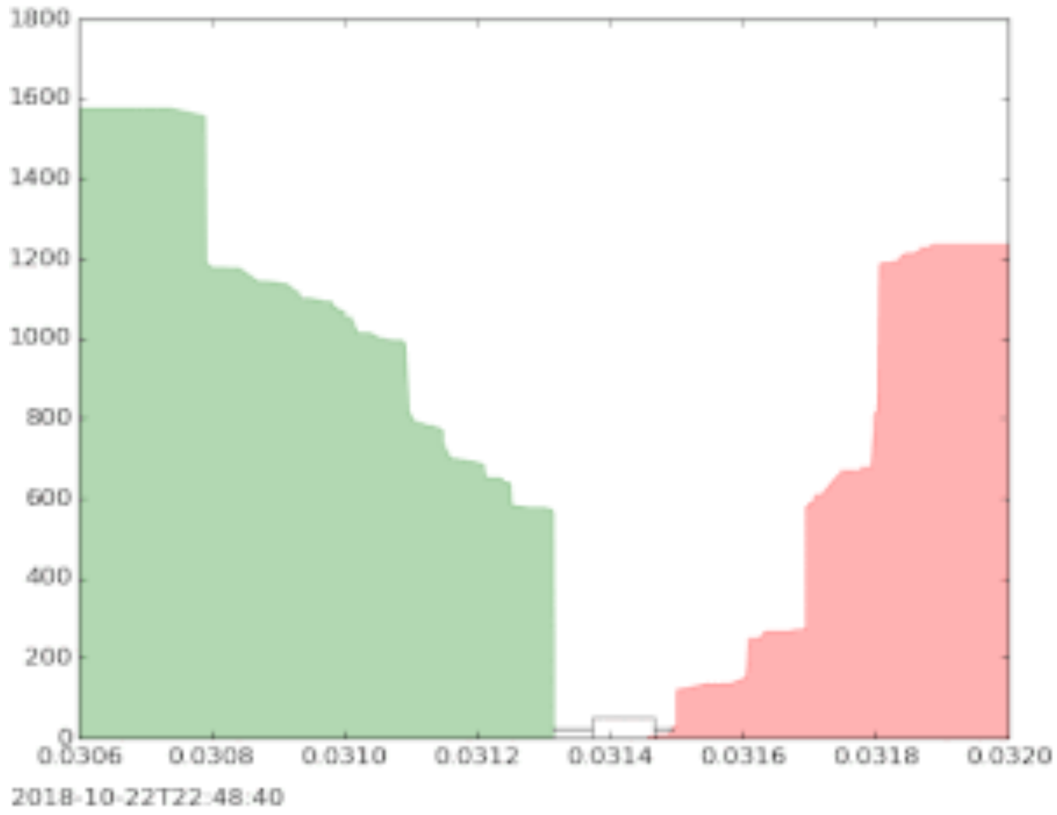
Section 3.1 of Strictly Proper Scoring Rules, Prediction, and Estimation by Gneiting and Raftery.

Connection to Prediction Market



Designing Automatic Market Makers

- Traditional market mechanisms might not work when the market is thin



Designing Automatic Market Makers

Goal of the market maker

Incentivize ***multiple*** agents to share their beliefs, and find a way to ***aggregate*** these beliefs into a unified prediction

1. Could use one scoring rule per agent, but not clear how to aggregate
2. Market itself is an aggregation mechanism (use final price as the prediction). However, standard stock-market-style trading might encounter issues for less popular predictions (market is too *thin*).

Market Scoring Rules

- See Hanson's papers in the optional readings of the Prediction Market lecture
- Intuitions: a "sequentially shared scoring rule"
  - An automatic market maker
  - Market maintains a vector of predictions $\vec{r}^{(t)}$
  - If a trader changes the vector from $\vec{r}^{(t)}$ to $\vec{r}^{(t+1)}$ and the outcome is w_i, the trader obtains reward

$$S\left(\vec{r}^{(t+1)}, w_i\right) - S\left(\vec{r}^{(t)}, w_i\right)$$

- Under some conditions:
  - Agents truthfully report their beliefs
  - The prediction will converge