Information Cascades

Machine Learning with Graphs

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Lecture Topics

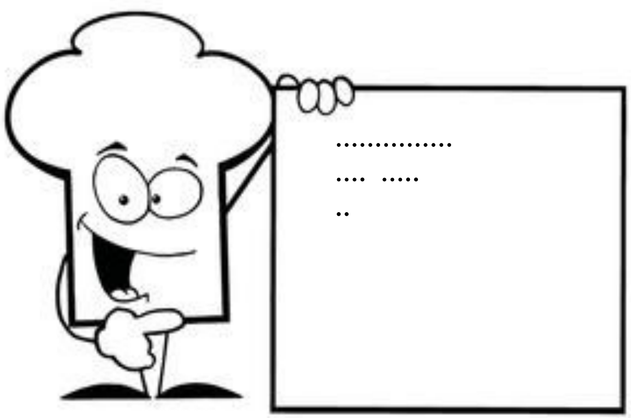
- **Information Cascades**
- Cascade Principles
- Simple Cascade Model

Following the Crowd

- Social relations enable people to **influence** each other's behavior and decisions.
  - opinions they hold,
  - political positions they support,
  - activities they pursue,
  - technologies they use, etc.
- **Information cascade**
  - behaviors that **cascade** from one node to another like an epidemic! and produce **collective outcomes**.
- We aim to reason about why such influence occurs!

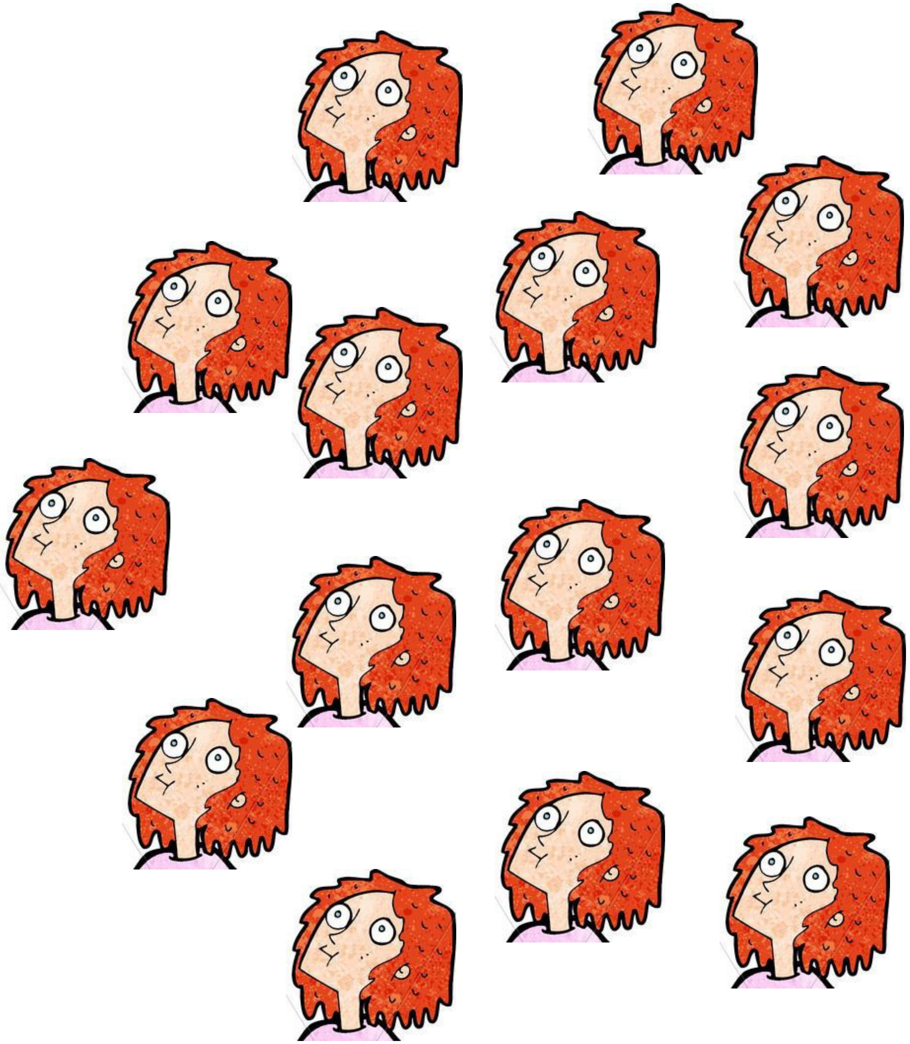
Following the Crowd- Cnt.

- Restaurant choice!



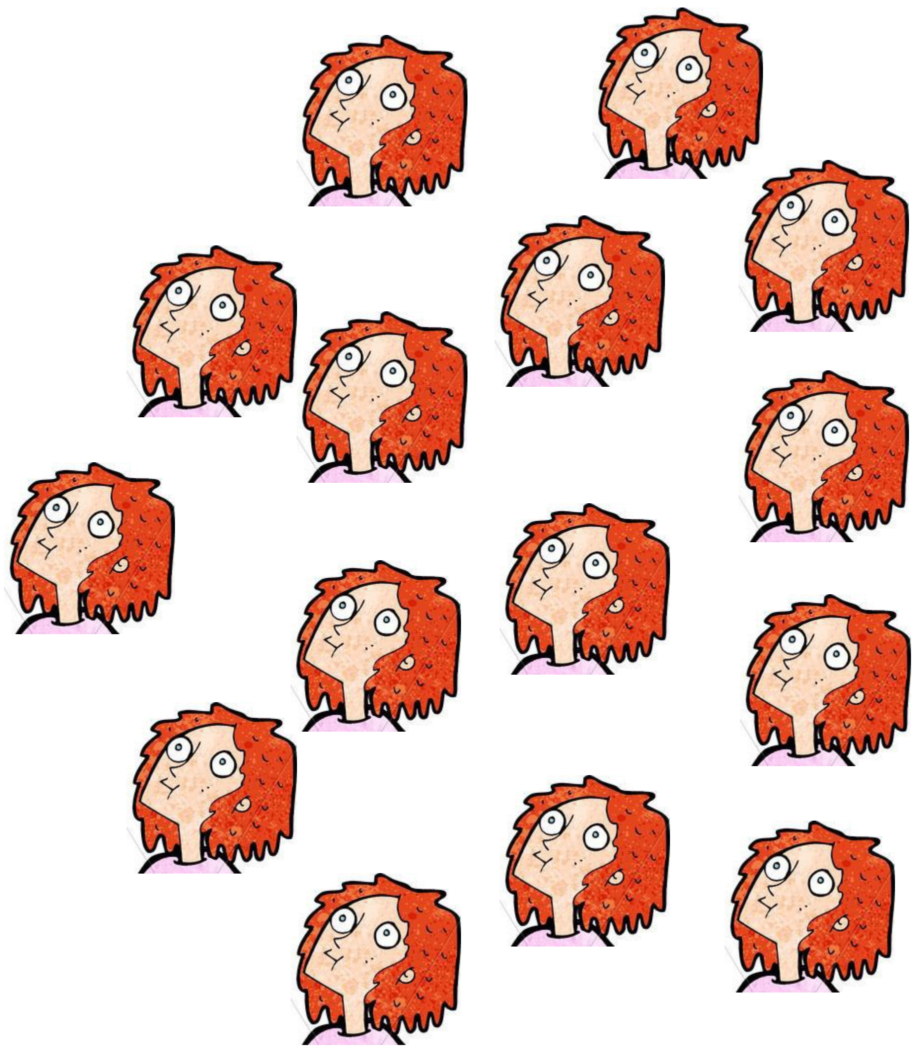
Following the Crowd- Cnt.

- Local Mind!
  - 15 people on a street corner stare up into the sky!!!
  - How many passersby stopped and looked up?



Following the Crowd- Cnt.

- Local Mind!
  - 15 people on a street corner stare up into the sky!!!
  - How many passersby stopped and looked up?
    - More people staring up more passersby stopped!
    - all people looking up 45% of passersby stopped!



Following the Crowd- Demo!

- How to start a movement!

Ideas worth spreading

Following the Crowd- Cnt.

- Information cascade often occurs when people **make decisions sequentially**, with later people watching the actions of earlier people.

- From these actions people infer something about what the earlier people know!

Cascade Framework

- There is a **decision** to be made
  - E.g., whether to adopt a new technology, wear a new style of clothing, eat in a new restaurant, or support a particular political position.
- People make decisions **sequentially**.
- People can **observe choices** made by those who acted earlier.
- Each person has some **private info** that helps to make decision.
  - A person **can't directly observe** the other's private info, but he/ she can observe what they do.

Cascade Example

$\frac{R}{B}$ $\frac{R}{B}$ $\frac{B}{B}$

- Urn with 3 (blue or red) marbles
- A large group of participants
- Each participant:
  - Draws a marble from the urn
  - Looks at the **color**
  - Places it back without showing others
  - **Guesses** whether the urn is majority-red or majority-blue.
  - Publicly announces his / her guess to others.

- What's the likelihood of urn being **majority-red** or **majority-blue**?

Cascade Example

- Urn with 3 (blue or red) marbles
- A large group of participants
- Each participant:
  - Draws a marble from the urn
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  - Publicly announces his / her guess to others.

- **majority-red** : 50% chance
- **majority-blue**: 50% chance

Cascade Example- Cnt.

- Participants who has guessed correctly receive rewards!
  - So they try to optimize their decisions!

- What should we expect to happen?

Cascade Example- Cnt.

2/3

- The First Participant
  - If it’s red marble
    - guess majority-red;
  - If it’s blue marble
    - guess majority-blue.
- First participant’s guess conveys **perfect information** about what he has seen.

$\frac{1}{2}$ $\quad$ $\frac{2}{3}$

$$P(\text{Maj-R} \mid \text{Red}) = \frac{\boxed{P(\text{Maj-R})} \times \boxed{P(\text{Red} \mid \text{Maj-red})}}{P(\text{Red})}$$

$$P(\text{Red}) = P(\text{Maj-Red}) * P(\text{Red} \mid \text{Maj-red}) + P(\text{Maj-Blue}) * P(\text{Red} \mid \text{Maj-blue}) = 1/2$$

Cascade Example- Cnt.

- The Second Participant
  - If (s)he sees the same color that the first participant announced, then
    - should guess this color as well.
  - sees the opposite color,
    - will be indifferent
      - Let's assume (s)he breaks the tie by guessing the color she saw.
- Thus, the 2nd participant draws conveys **perfect information** about what (s)he has seen.

Cascade Example- Cnt.

- The Third Participant
  - If the first two guessed opposite colors, then
    - the third should guess the color (s)he sees!
  - If the first two guesses have been the same (say both blue)
    - If third participant draws blue.
      - Simple!
    - If third participant draws red.
      - 3 draws from the urn:
        - blue, blue, red. All perfect information!
      - Guess that the urn is majority-blue! ignoring his own private information
        - Which, taken by itself, suggested that the urn is majority-red!

Cascade Example- Cnt.

- If first two guesses are the same, the third should be the same as well, regardless of which color was drawn.

- An information cascade has begun!
  - The third participant makes the same guess as the first two, regardless of his own private info!

Cascade Example- Cnt.

B B B

- The Fourth Participant and Onward!
  - Let's consider just the cascade case:
    - First two guesses were the same, say blue.
    - 3rd guess has to be blue too.
  - 4th participant, heard
    - blue, blue, ~~blue~~! —
    - First 2 guesses conveyed perfect info
    - 3rd guess conveys **no** info.
      - It has to be blue no matter what (s)he saw.
  - 4th is in exactly the same situation as 3rd!
    - should guess blue regardless of what (s)he sees.
  - This will continue with all subsequent participants:
    - If first 2 guesses were blue, then everyone will guess blue!

Cascade Example- Cnt.

Summary

- If participant 1 & 2 make the same decision:
  - All will follow this regardless of his signal.
- 3's decision conveys no info!
- Future participants will all be in the same position as participant 3.
- In this case, a cascade has begun.

Lecture Topics

- Information Cascades
- **Cascade Principles**
- Simple Cascade Model

General Cascades Principles

1. Cascades can easily occur, given the right structural conditions!
   - Based on very little information,
   - **Pre-cascade information** influences the behavior of the population.

General Cascades Principles- Cnt.

2. Cascades can lead to non-optimal (wrong) outcomes!
   - Say the urn is majority-red!
   - Chance of the first two participants *draw* blue marbles is small:
     - and thus all others wrongly *guess* blue!

General Cascades Principles- Cnt.

3. Some (*but not all*) cascades can be very fragile!
   - Suppose first 2 guesses are blue
   - Participant x and $x+1$ draw red and "show" it to others!
   - $x+2$ has four pieces of **perfect info**:
     - blue (1), blue (2), red (x), red ($x+1$)!
     - Decide based on his / her own draw!

Lecture Topics

- Information Cascades
- Cascade Principles
- **Simple Cascade Model**

Cascade Model

- Consider a group of people (1, 2, …) who make decisions **sequentially**
  - decision: **accept** or **reject** some **option**, e.g. adapting a new tech. or voting for a candidate!
- Private signal (info)
  - Each individual gets a *private* signal indicating if accepting is a good or bad idea (*not perfect*).
- Two States:
  - the option is a good idea (G) with probability p
    - $Pr[G]=p$
  - it's a bad idea (B) with probability $1-p$.
    - $Pr[B]=1-p$

The aggregation of private signals convey perfect information about the correct action.

Cascade Model- Cnt.

- Payoffs: individuals receive payoffs based on their decision to accept or reject the option
  - If reject, payoff = 0.
  - If accept and option is a good idea, payoff= $v_g > 0$
  - If accept and option is a bad idea, payoff= $v_b < 0$
- Expected payoff in the absence of other info is 0;
  - $v_g p + v_b (1 - p) = 0.$
  - before getting any additional info, payoff from accepting is the same as the payoff from rejecting.

Sequential Decision-Making

- Let's consider the perspective of a person.
  - Suppose person N knows that everyone before her has followed their own signal (**a**ccept / **r**eject)!
- If $a = r$ (among people before N), then
  - N will follow her own signal.
    - N's signal will be the tie-breaker
- If $|a - r|=1$, then
  - N will follow her private signal
    - either N's private signal will make her indifferent or reinforce the majority signal.
- If $|a - r|>=2$, then
  - N follow the earlier majority & ignore her own signal.

Sequential Decision-Making- Cnt.

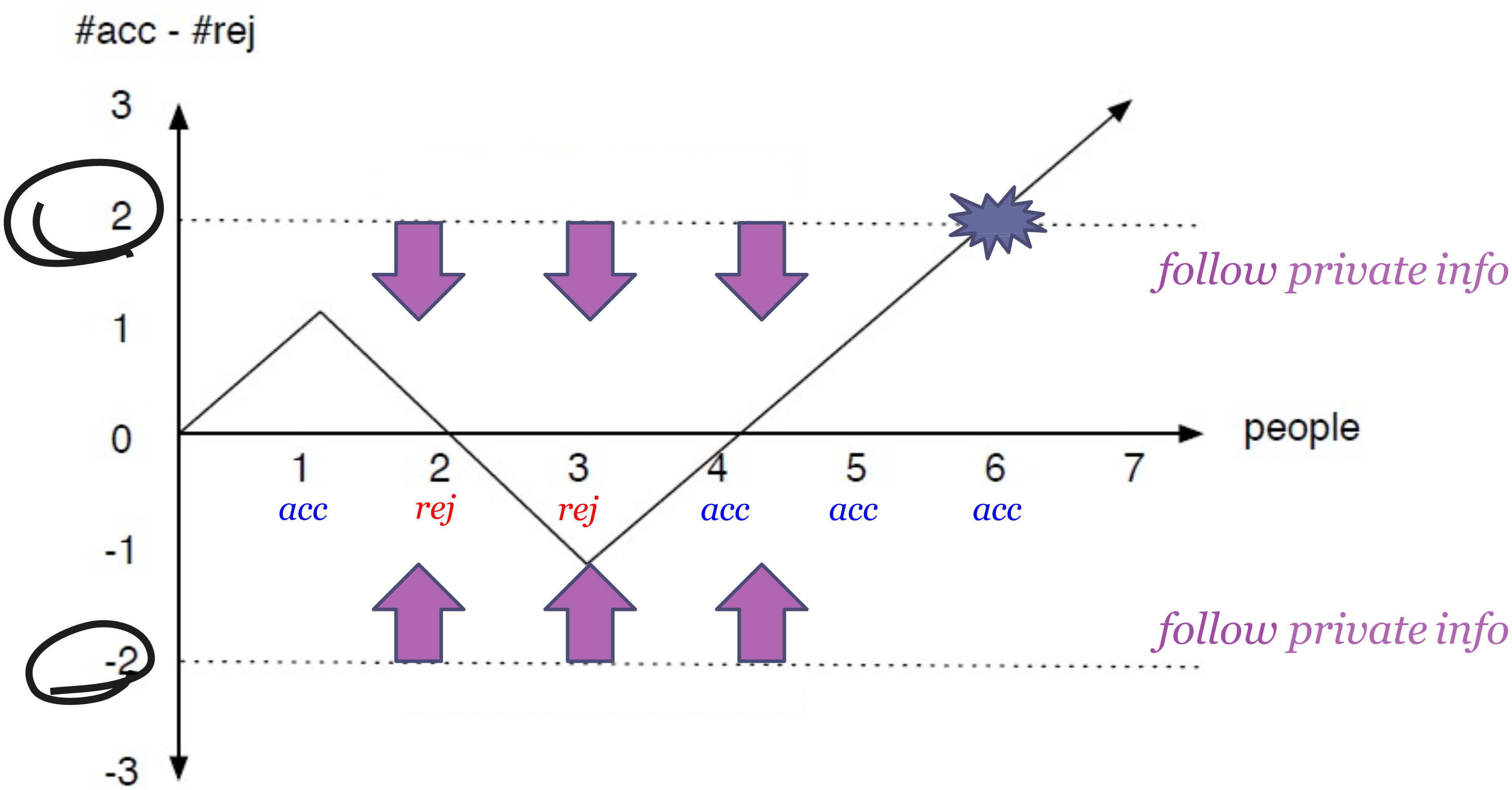


Figure 16.3: A cascade begins when the difference between the number of acceptances and rejections reaches two.

Sequential Decision-Making- Cnt.

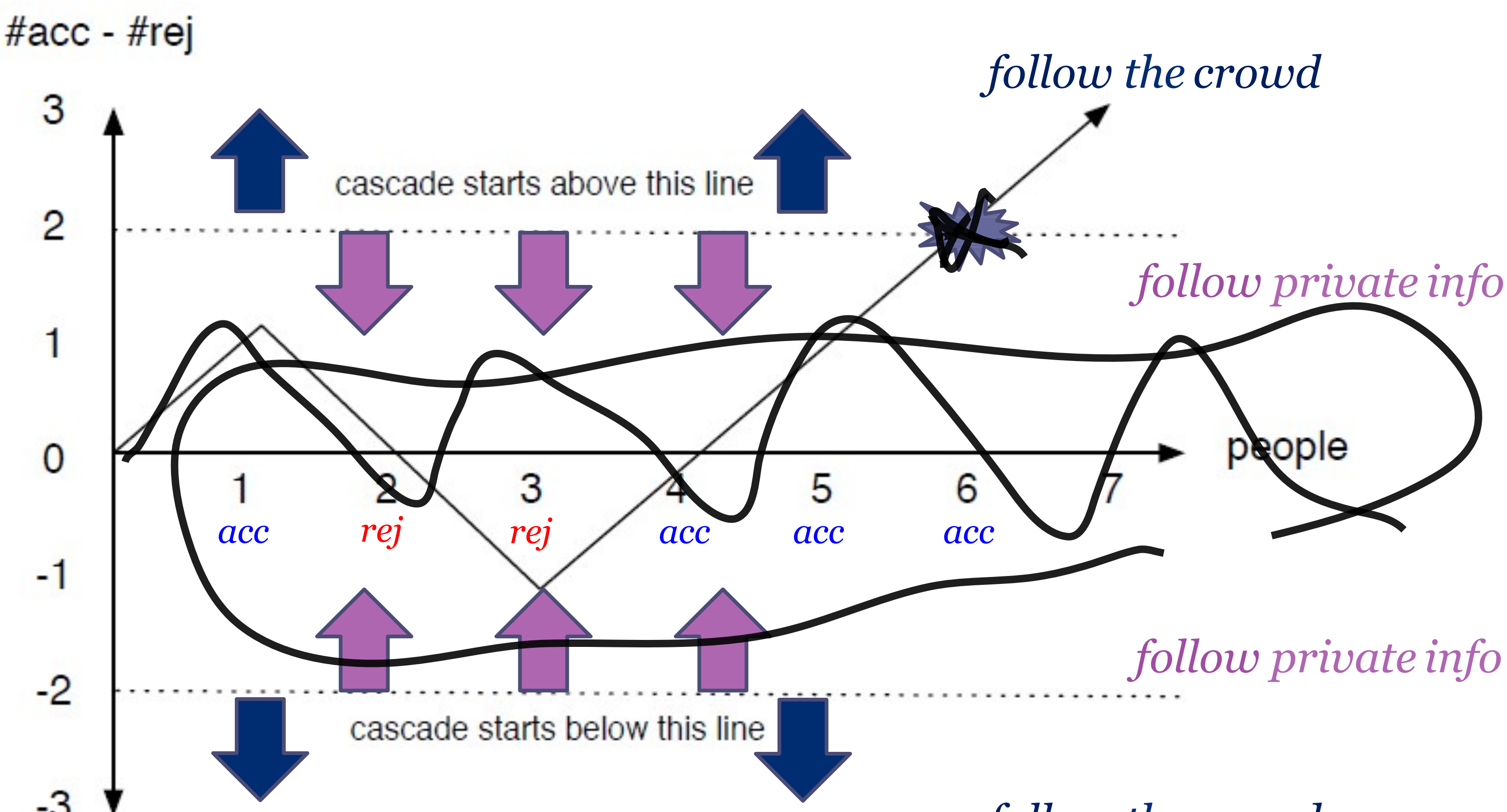


Figure 16.3: A cascade begins when the difference between the number of acceptances and rejections reaches two.

Sequential Decision-Making- Cnt.

- It is very hard for $(a - r)$ to remain in such a narrow interval (btw -1 and +1)
  - For example, if 3 people in a row get the same signal, a cascade will definitely begin.

Sequential Decision-Making- Cnt.

- **Claim**: The probability of finding 3 matching signals in a row converges to 1 as the number of people N goes to infinity.

- **Hint**:
  - Divide the first N people into blocks of 3 people

Sequential Decision-Making- Cont.

- **Claim**: The probability of finding 3 matching signals in a row converges to 1 as the number of people N goes to infinity.
- **Solution**:
  - Divide the first N people into blocks of 3 people
    - **[1, 2, 3]**; **[4, 5, 6]**; and so on
    - People in one block receive same signal with probability
      - $q^3 + (1 - q)^3$
    - The probability that none of these blocks consists of identical signals is then
      - $[1 - (q^3 + (1 - q)^3)]^{N/3} \rightarrow 0$
      - As N goes to infinity this quantity goes to 0.

Sequential Decision-Making- Cnt.

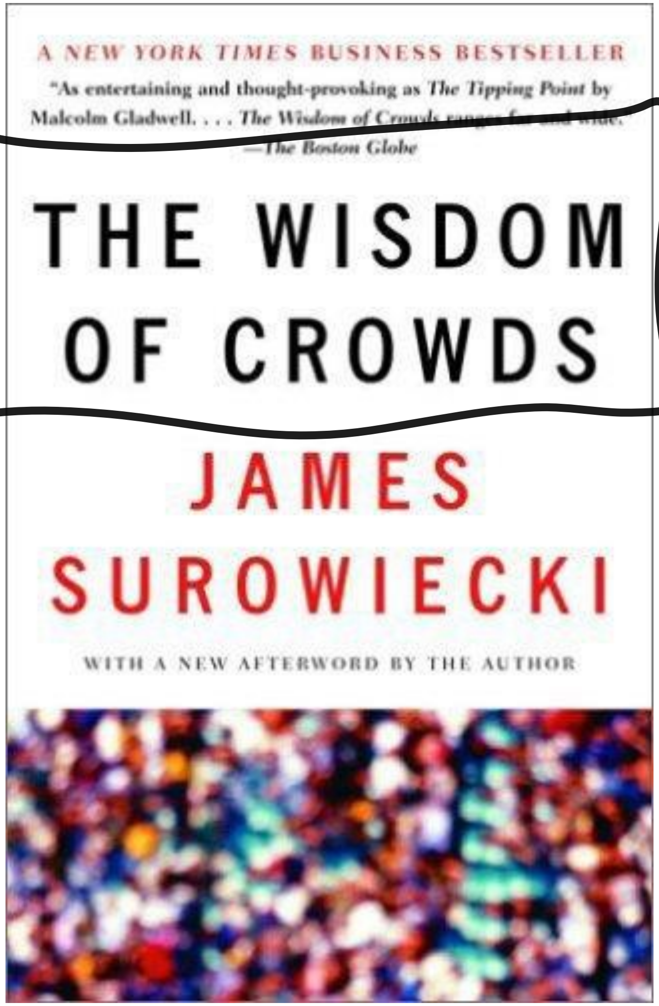
- Different variations of the same problem:
  - What if people **don't see all the decisions** made earlier but only some of them?
  - What if private signals convey **information with different level of certainty**?
  - What if different people receive **different payoffs**?

q

$1-q$

Lessons from Cascades

- The **aggregate behavior** of many people with limited info can produce **very accurate results**.
  - If many people are guessing **independently**, then the average of their guesses is often a good estimate
    - Number of jelly beans in a jar!
    - Weight of a bull at a fair!



Lessons from Cascades- Cnt.

- But in cascades, people guess **sequentially**, and
  - Can **observe the earlier guesses** of others,
  - **being influenced** by them,
  - **Conform to majority**!

Lessons from Cascades- Cnt.

- Tension in collaboration
  - Hiring Committee
    - decide if to make a job offer to candidate A or B
    - cascade may develop quickly:
      - A few people initially favor A, others may conclude that they should favor A, even if they initially preferred B!

- Balancing the tension
  - Ask experts to make partial decisions independently before collaboration phase!

Lessons from Cascades- Cnt.

- Marketers use the idea of cascades too!
    - To initiate a **buying cascade** for a new product.
    - Induce an initial set of people to adopt a new product,
    - Other consumers later on may also adopt the product!
        - Even if its worse than competing products!

- Most effective if later consumers are able to observe
    - the adoption decisions (guesses),
    - but not how satisfied the early buyers are (ball color).

Reading

- Ch.16 Information Cascades [NCM]