Applications of probability

CE311S, March 29, 2018

Guest lecture

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Why care about today's lecture?

Probability

- Study of how random processes behave
- Recall: randomness (in some ways) means anything which is currently unknown, but is important for some reasons

Statistics

- Study of how can we use data and experiments to understand random processes

Why care about today's lecture?

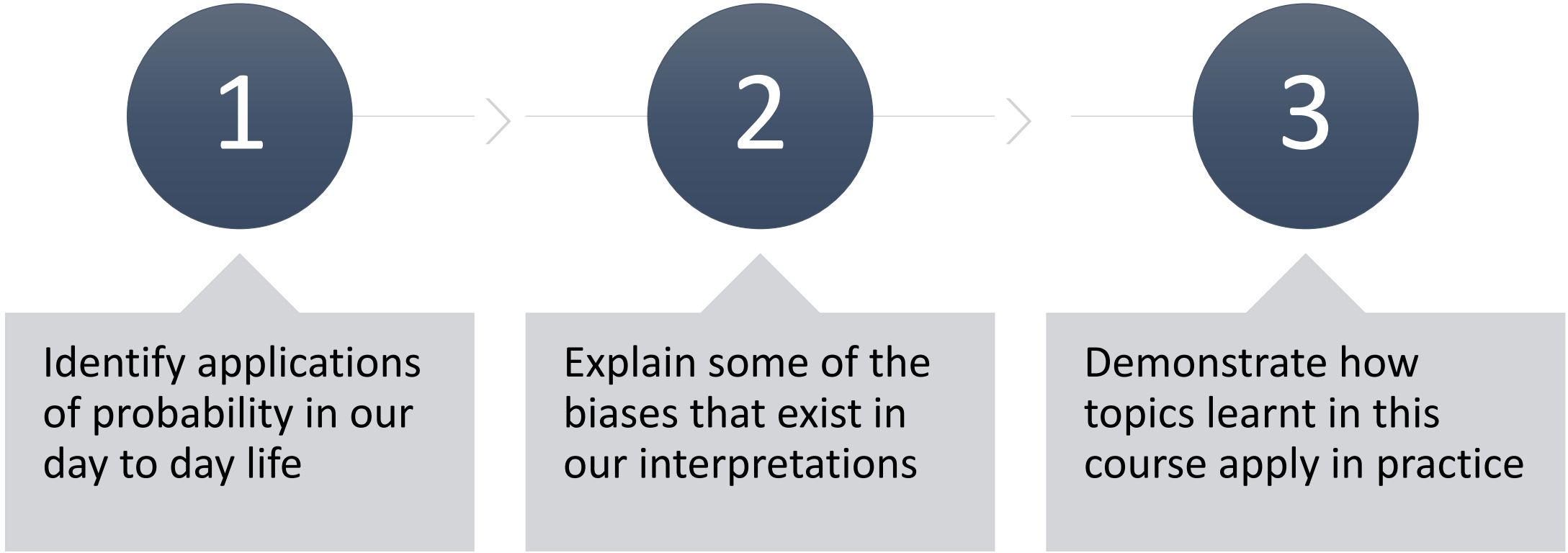
What we have learnt?

- Set theory and axioms of probability
- Conditional probability, Bayes' theorem
- Random variables
- Discrete and continuous random variables
- Joint random variables and marginal PDFs
- Expected values, variance, covariance

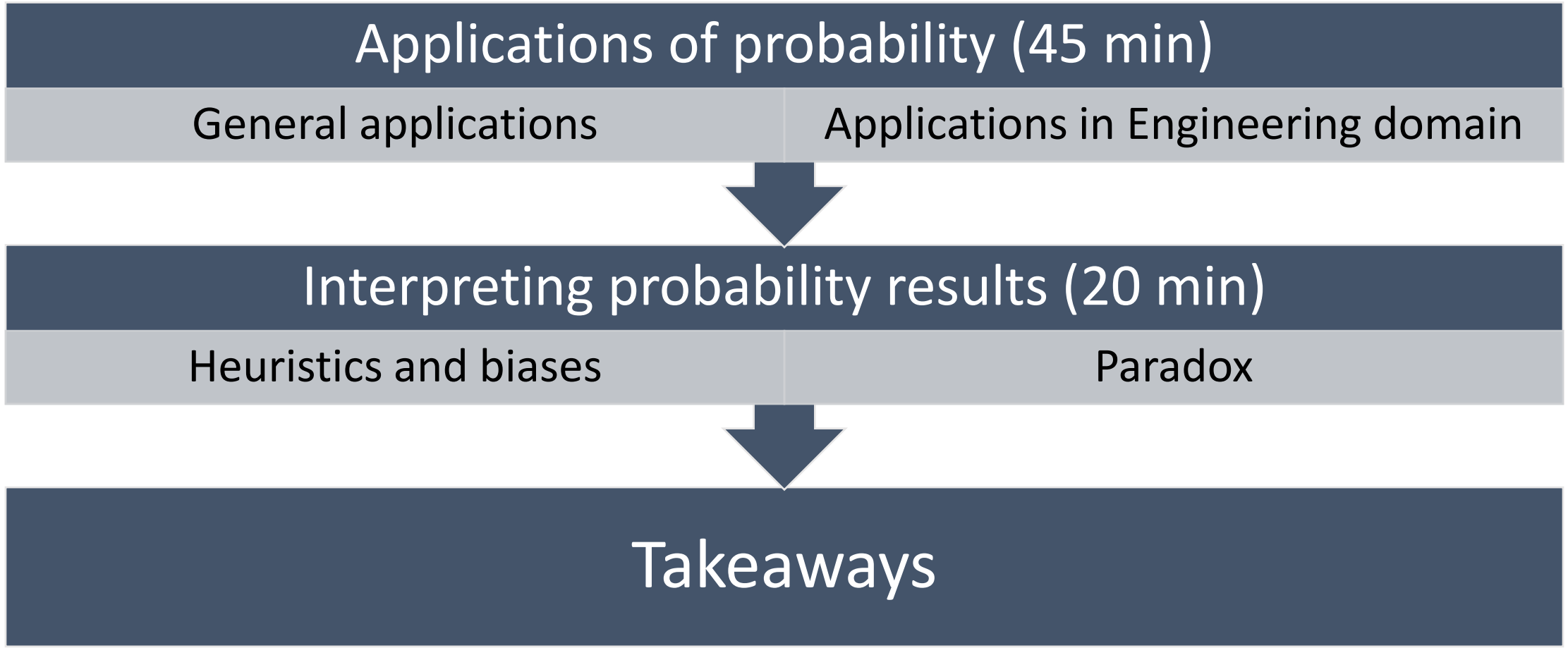
Applications all around us

- "It is very certain that, when it is not in our power to determine what is true, we ought to act according to what is most probable." – Rene Descartes

Learning outcomes



Outline


Applications of probability (45 min)
General applications
Applications in Engineering domain
Interpreting probability results (20 min)
Heuristics and biases
Paradox
Takeaways

Activity 1: Uncertainty around us

- Write down 2 examples or applications around you that involve randomness

- Think creatively

Hurricane

- Goal: Predicting movement of hurricanes given certain historic and real-time measurements
- Random variables
  - Position, speed, bearing, atmospheric pressure…
- **Error cone (or cone of uncertainty)** provided by National Hurricane center

NCAA March Madness brackets

- Goal: predict which team wins in each bracket

- Random variables:
  - Players' likelihood to score a two pointer

Amazon acquiring whole foods

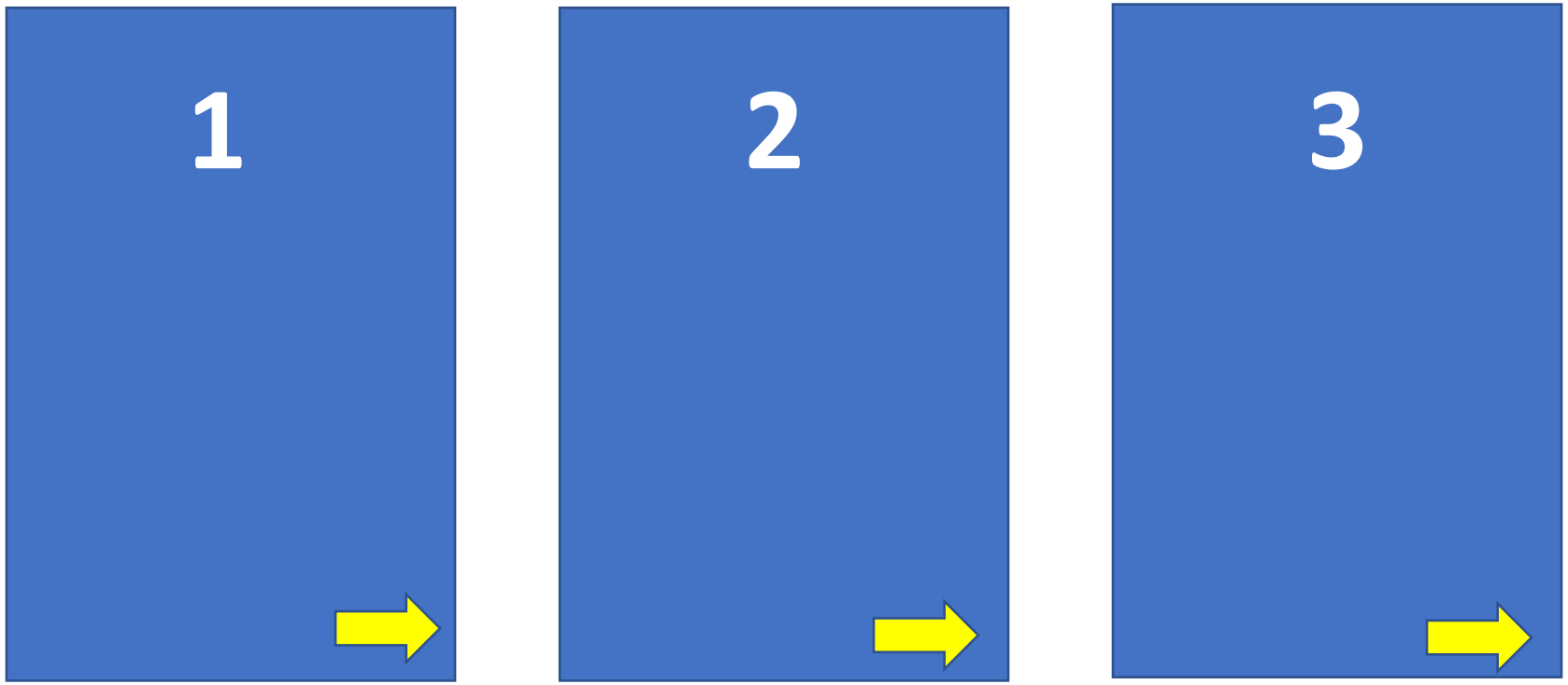
- Is it a smart business move in the long term?
- What will the future revenue and costs be?

- Random variables:
  - revenue, cost, number of items sold, …

Games, gambling, and lotteries

- Predicting probability of success
- Identifying whether to participate or not
- Expected profit made at a gambling station

Let’s Make a Deal



Let’s Make a Deal

2

3

Let’s Make a Deal

1

3

Let’s Make a Deal

1

2

Let’s Make a Deal

Let’s make a deal explained

Behind door 1	Behind door 2	Behind door 3	Result if staying at door #3	Result if switching to the door offered
Car	Goat	Goat	Wins goat	**Wins car**
Goat	**Car**	Goat	Wins goat	**Wins car**
Goat	Goat	**Car**	**Wins car**	Wins goat

Other applications include

Finances	• Risk of stock market; whether to buy or sell products
Medicines	• Whether a new medicine is effective in treating a disease?
Disaster management	• When and where will the disaster happen?

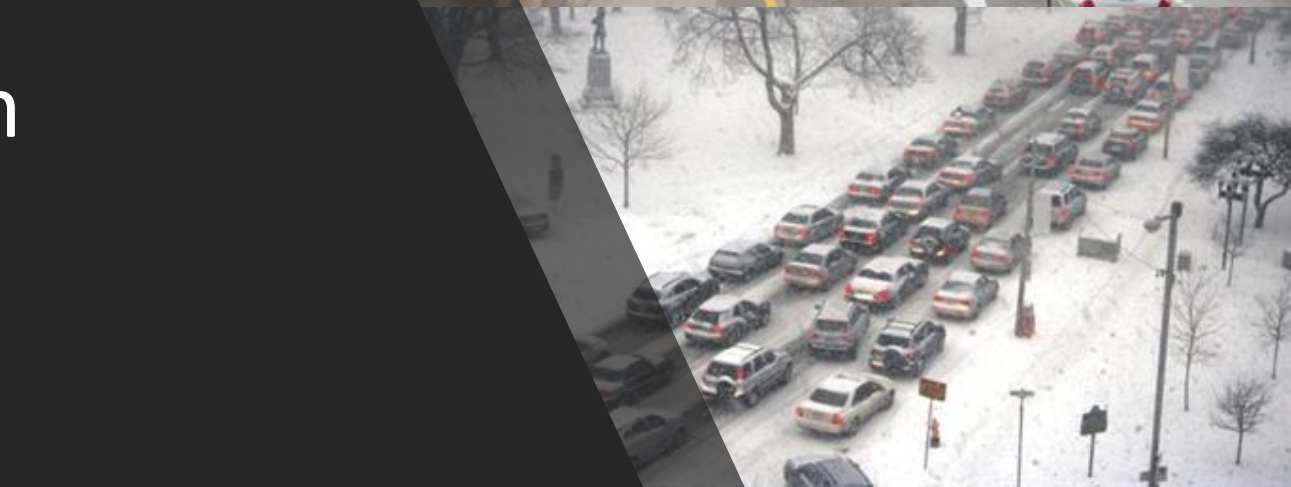
Guess some civil engineering applications

- Structures:
  - What wind load should we design a building to withstand?
- Transportation:
  - Where will people live and work in 30 years?
- Water Resources:
  - How can we manage reservoirs knowing there will be both droughts and flood years?
- Construction Management:
  - How long will a project actually take, and at what cost?
- Geotechnical:
  - What kind of soil actually exists where the foundation will be?

Traffic delay

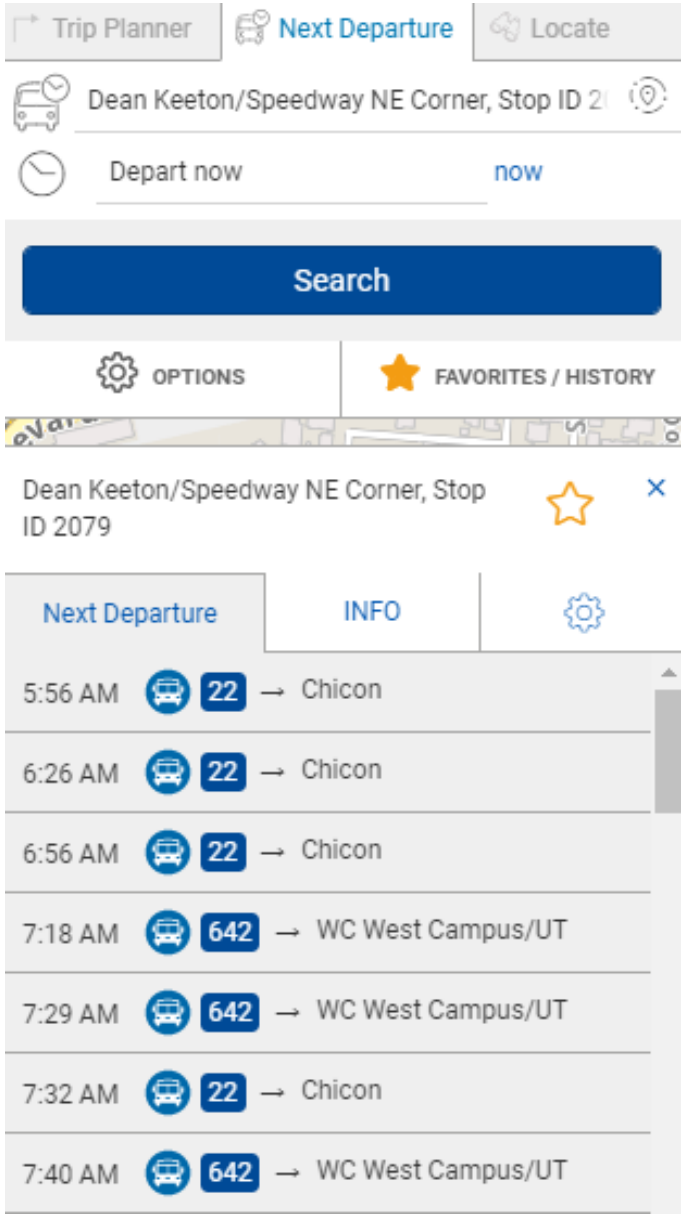
- Non-recurrent congestion
  - Work zones
  - Incidents
  - Weather

- What could be the random variables?

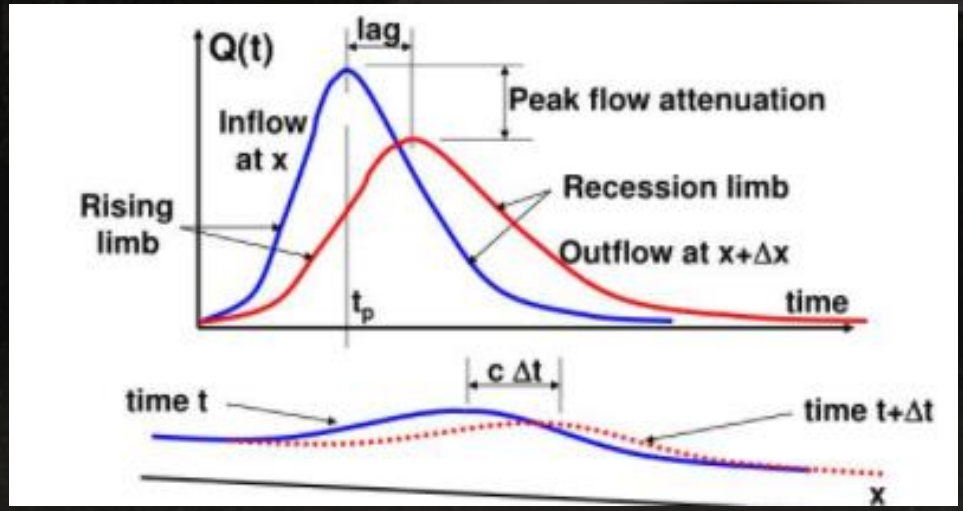


Reliability of public transportation

- Will the bus arrive at the same time it is scheduled for?
- Random variables?



Flash flooding



Predicting flash flood intensity

Formulating inflow model

Application from my research

- Dynamic tolling of express lanes
- Traffic demand uncertain
  - Certain day has more traffic than the others
- Whether drivers choose express lane is uncertain

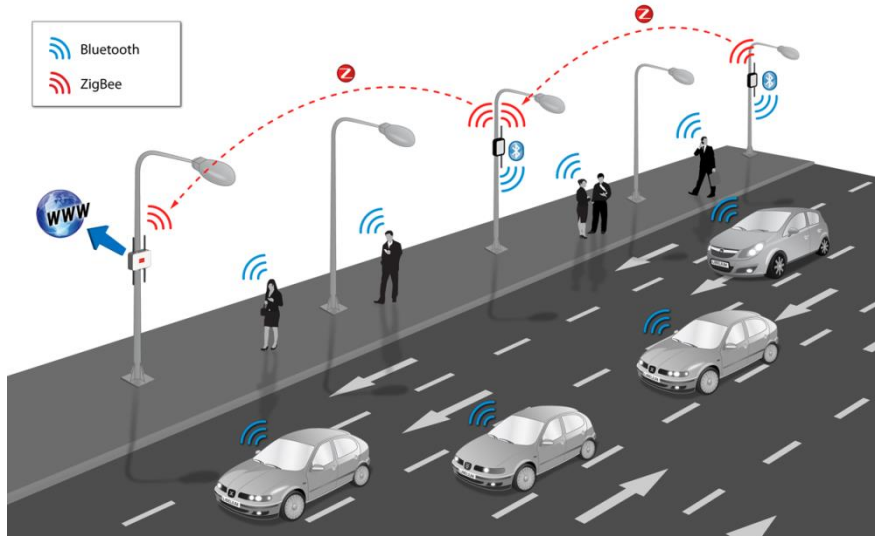
- Traffic flow is uncertain
  - Lane changes and merge/diverge/weaving

Other research frontiers

Traffic state estimation

Training autonomous robots

Netflix recommender system



Interpretation of probability

Heuristics and biases

"We are **prone to overestimate** how much we understand about the world and to **underestimate the role of chance** in events."

"The confidence that individuals have in their beliefs depends mostly on the quality of the story they can tell about what they see, even if they see little."

Quotes from "Thinking Fast and Slow" by Daniel Kahneman

Availability heuristic

- The tendency to **overestimate the likelihood of events** with greater "availability" in memory, which can be influenced by how recent the memories are or how unusual or emotionally charged they may be

- Example:
  - Why are more people afraid to fly than to ride in a car?
  - Why are death due to sharks more worried upon than death from falling airplane parts?

Ambiguity effect

- The ambiguity effect is a cognitive bias **where decision making is affected by a lack of information**, or "ambiguity“
- Example:
  - When buying a house, people choose fixed mortgage over variable rate mortgage (depending on the market) even though the latter is more profitable statistically
- Risk-averse vs Risk-neutral
  - People have a bias to be risk-averse in general
  - However, taking risks in certain situations leads to greater profits

Correlation vs Causation

- **Causation** indicates that one event is the result of the occurrence of the other event; i.e. there is a causal relationship between the two events
- A **correlation** between variables, however, does not automatically mean that the change in one variable is the cause of the change in the values of the other variable.
- Examples of mistakes:
  - In medical research, one group may receive a placebo while the other group is given a new type of medication. If the two groups have noticeably different outcomes, the different experiences may have caused the different outcomes

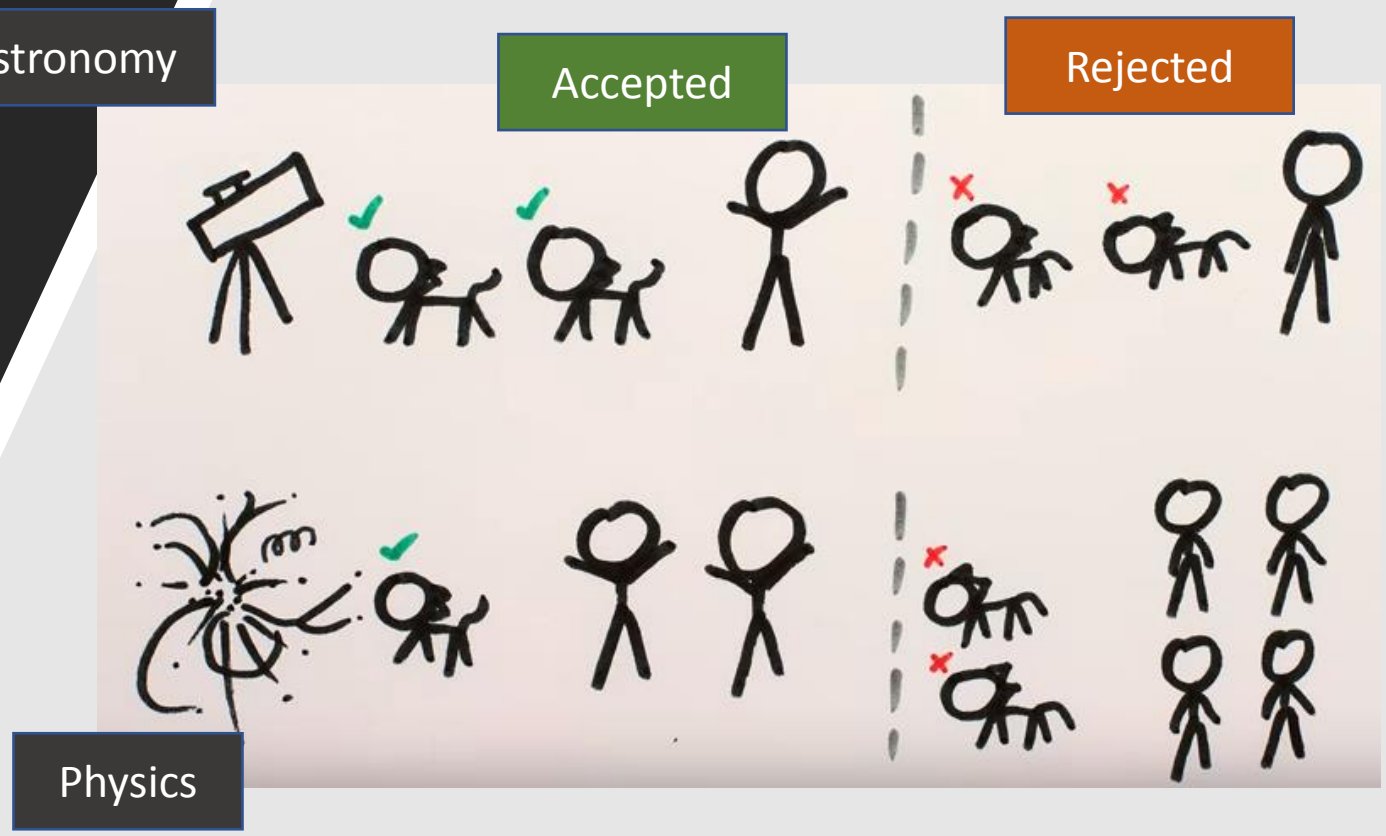
University of cats and humans: Group exercise

Cats and Humans apply to a same university's Astronomy and Physics department

43% cats gets admitted; 37% humans get admitted

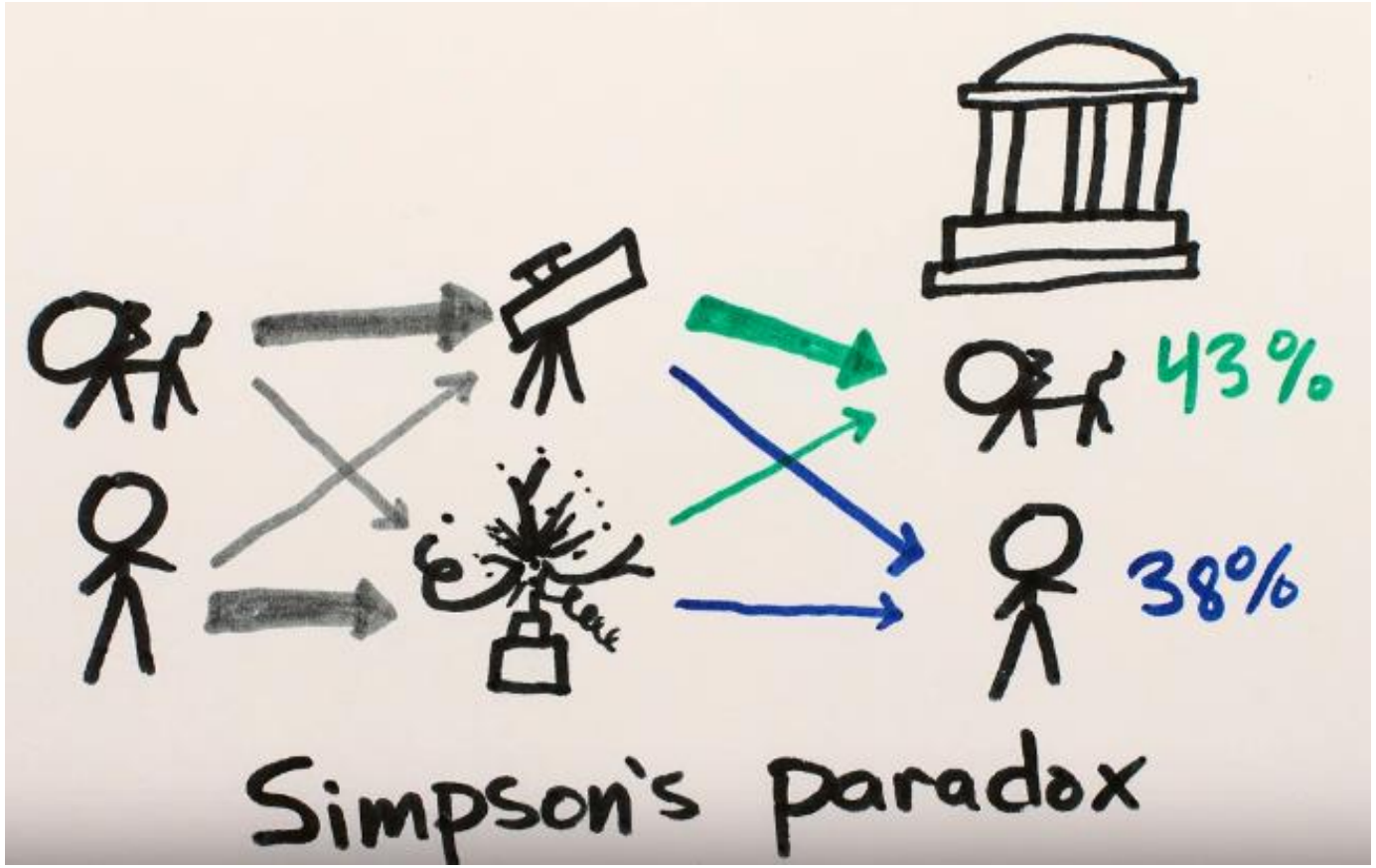
Humans claim that they are being discriminated against in the admission process. **Would you agree or not?**

What is happening?



Simpson’s Paradox

- Lesson: Same set of data can lead to different interpretations.



Takeaways

What are the primary takeaways?

- **Take notice of the uncertainty**, data, and numbers around you
  - Question the assumptions
- Learn what the **actual probabilities** are before making important decisions. And realize that **people are not always rational**, especially regarding uncertain events
- When modeling a complex uncertain process, **start with the fundamentals**
  - "All models are wrong but some models are useful"
- **Stay curious** about the interdisciplinary nature of probability and statistics in several cool domains
  - How does Google rank webpages?