FMS1203S: Randomness in scientific thinking

Week 1

FMS1203S: Randomness in scientific thinking

Time: Wednesdays, 4-6pm

Venue: S16-03-09

Instructor: Chen Zehua

- Office: S16-07-108
- Email: stachenz@nus.edu.sg

Course Outline

The purpose of this seminar is to introduce you to the roles of randomness in scientific thinking. It will help you to understand questions including the following:

- Is probability intuitive?
- What is the role of randomization in the design of scientific experiments?
- How has statistical thinking been used and abused?
- How can physical understanding embedded in deterministic models be reconciled with statistical approaches to quantifying uncertainty and risk?
- How can random numbers generated on a computer do complicated calculations that aren't easily done by other means?
- Why is statistical thinking crucial in modern scientific enquiries involving massive databases?

Course structure

Weekly workload

- 2 hours of seminars
- 8 hours of assignments, projects and preparatory work

Class format

- Each class has two parts.
  - (i) (75 minutes): 5 presentations. Each presentation consists of a 12-minute (max.) talk and a 3-mininute Q&A.
  - (ii) (15 minutes): Introduction of the topics for the next week.
- You are going to work in groups of three, each group will prepare and give a presentation based on the reading materials each week. The members in each group will take turns for the presentation.
- The presenter should upload the slides in the IVLE workbin in advance. The file name should include Group #, Week # and the name of the presenter.

Course structure (cont.)

Course Materials

- The reading materials include science news, popular science books, and scientific journal articles.
- The reading matrerials will be assigned by the instructor, but you are also welcome to find your own reading materials related the topics of the week.
- The assigned books can be found in the RBR of the Science library. Some assigned reading materials will be uploaded on the IVLE workbin.

Assessment

- A satisfactory/unsatisfactory final grade will be given. The grade will be based on a numerical score which assesses your performance in attendace, contribution to class discussion, final written report and class presentation.
- The final written report is to be handed in at the end of the semester. The report should be two pages long and include the topics you have learned or heard in the semester. The report should mimic the writing style of scientific journal articles (the structure, the wording, the references, etc.)
- The weightage of the score is as follows:
  - 10% for attendance
  - 10% for contribution to class discussion
  - 20% for your written report
  - 60% for your class presentations

Advantage of taking the FMS module

- Interactive, independent and peer-based learning.
- Relaxed and non-examination style.
- Ability to choose area of study and voice out opinions freely.
- Enables bonding among classmates.
- Personal development: skills that will help your future studies/career plans:
  - Presentation
  - Team working
  - Learn how to read scientific literature
  - Learn how to write scientifically
  - Critical thinking
  - Better common sense

Guidlines on presentation

- Know your audience.
- Understand everything you present.
- Provide an outline and organize your slides logically into sections.
- Make your slides vivid and impressive, use pictures and figures for summary or illustration while possible.
- Get the main ideas across, leave out the details.
- Talk about 30s to 2min per slide.
- Provide a take-home Message.

Group Membership

- Group 1: Chia Boon Xuan; Fatin Khairunnisa Bte M K; Lee Mei Ying.
- Group 2: Tan Soon Guan; Nurul Nabilah Bte Kamal M; Chang Jing Kai.
- Group 3: Bok Wen Xuan; Goe Jie Sheng; Fong Jing Yi, Annabella.
- Group 4: Chan Yong Ming; Kwek Zi Wei, Bernetta; Ng Shu Min.
- Group 5: Peh Ching Hui, Timothy; Toh Yan Ling; Yang Yi Mou.

During the break: Get to know each other

- Identify your group members.
- Self introduction.
- Conduct a mutual peer interview using the interview form provided.
- Exchange contact information after the class.

Topic for next week:

How small probabilities affect our life?

Reading assignments for next week:

- Group one: Mlodinow, L. (2008). The drunkard's walk: how randomness rules our lives. London: Penguin, pp. 21–40 (Chapter 2, The law of truths and half truths).
- Group two: Franklin, J. (2009). What science knows: and how it knows it. New York: Encounter Books, pp. 161–180. (Chapter 10, Probabilities and risks).
- Group three: Mlodinow, L. (2008). The drunkard's walk: how randomness rules our lives. London: Penguin, pp. 192–219 (Chapter 10, The drunkard's walk).
- Group four: Rosenthal, J. (2005). Struck by lightning: The curious world of probabilities. London: Granta Publications, pp. 234–246 (Chapter 16, Ignorance, Chaos, and Quantum Mechanics).
- Group five: Fienberg, Stephen E. and Stern, Paul C. (2005). In Search of the Magic Lasso: The Truth About the Polygraph. *Statistical Science*, 20, 249-260.

A few probablility results for facilitating our discussion

Conditional probability

- Our probabilistic assessments of uncertainty should change as new information becomes available. Suppose we receive the piece of information that event B has happened.
- What should our assessment of the probability of another event A be in the light of this new state of knowledge? We write $P(A|B)$ for the probability of A given that B has happened.
- The definition of $P(A|B)$ is

$$P(A|B) = \frac{P(A \cap B)}{P(B)}$$

provided $P(B) > 0$.

A few probablility results for facilitating our discussion

Example: roll a fair die

- Suppose we roll a fair die (we assume that all 6 faces are equally likely, probability 1/6 for each).
- Suppose A is the event of rolling a 2, and B is the event of rolling an even.
- Note here that $A \cap B = A$, and $P(A \cap B) = 1/6$. Also, the probability of an even, $P(B)$ is $1/2$.
- Although $P(A) = 1/6$ if we know that B happened,

$$P(A|B) = \frac{P(A \cap B)}{P(B)} = \frac{1/6}{1/2} = \frac{1}{3}.$$

A few probablility results for facilitating our discussion

Multiplication rule

$$P(A \cap B) = P(A)P(B|A) \quad P(A) \neq 0$$
$$P(A \cap B) = P(B)P(A|B) \quad P(B) \neq 0$$

In words, the first formula just says that the probability of A and B both happening is just the probability of A happening, times the probability of B happening given that A has happened.

Law of total probability

$$\begin{aligned} P(A) &= P(A \cap B) + P(A \cap B^c) \\ &= P(B)P(A|B) + P(B^c)P(A|B^c) \end{aligned}$$

The story of the large hadron collider

To find facts about LHC, visit
https://press.cern/backgrounders/facts-figures

Probability of catastrophe

- The Large Hadron Collider (LHC) is the most powerful particle accelerator ever built, designed to probe the structure of matter through high energy particle collisions.
- A legal challenge was mounted to the start-up of the LHC, on the grounds that it might annihilate the earth by creating a black hole or a deadly shard of strange matter.
- Physicists have disputed the suggestion that the LHC is not safe, and their calculations put the probability of catastrophe at around 10^{-9} per year, a very small value.

The story of the large hadron collider

Probability of catastrophe: another calculation

- A recent analysis by Toby Ord and his colleagues at the Future of Humanity Institute at Oxford argued somewhat differently, and highlighted the difficulties involved in the calculation of very small probabilities.
- Let

$$\begin{aligned} C &= \{\text{Catastrophe}\} \\ U &= \{\text{Known physics gives correct calculation}\}. \end{aligned}$$

Then

$$\begin{aligned} P(C) &= P(C \cap U) + P(C \cap U^c) \\ &= P(U)P(C|U) + P(U^c)P(C|U^c) \end{aligned}$$

The story of the large hadron collider

The argument of higher risk

- Ord and his colleagues argue that although $P(C|U)$ might be of the order 10^{-9} according to physicists calculations, if $P(U^c)$ is larger than this (for example, 10^{-6}) then it is the second term in the expression above that is dominant in calculating the real risk of catastrophe.
- Since the LHC is being built to probe realms in which the physics is not well understood, presumably $P(U^c)$ (i.e. the probability that known physics does not give the correct risk calculation) might be appreciable.
- This is not to say that the LHC is not safe, but it does highlight the difficulties of calculating small risks in the face of uncertainty.