Lecture 7

Introduction to Probability

Text: Chapter 4

STAT 8010 Statistical Methods I

September 3, 2019

Whitney Huang
Clemson University

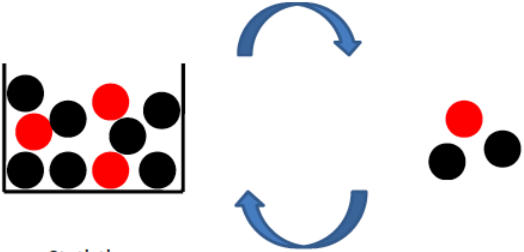
Agenda

1. **Probability and Statitics**

2. **Basic Concepts of Probability**

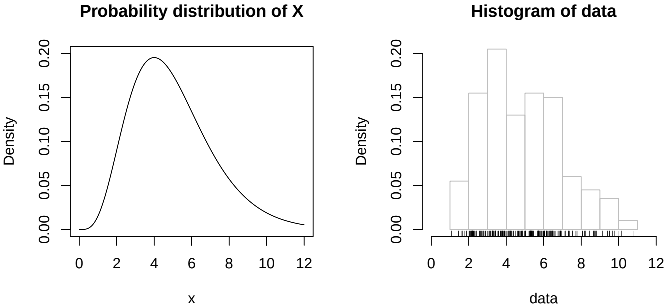
Probability and Statistics

<u>Probability</u>:
What is the probability to get 1 red and 2 black balls?



<u>Statistics:</u>
What percentage of balls in the box are red?

Probability and Statistics



Definitions

The framework of Probability is based on the paradigm of a random experiment, i.e., an action whose outcome cannot be predicted beforehand.

- Outcome: A particular result of an (random) experiment. (e.g. rolling a 3 on a die roll)
- Event: A collection of one or more outcomes of an experiment. (e.g. rolling an odd number on a die roll)
- Sample space: the set of all possible outcomes for an experiment. We will use Ω to denote it
- Probability: A number between 0 and 1 that reflects the likelihood of occurrence of some events.

Example

We are interested in whether the price of the $S\&P$ 500 decreases, stays the same, or increases. If we were to examine the $S\&P$ 500 over one day, then $\Omega = \{$decrease, stays the same, increases$\}$. What would Ω be if we looked at 2 days?

Solution.

Example

Let us examine what happens in the flip of 3 fair coins. In this case $\Omega = \{(T, T, T), (T, T, H), (T, H, T), (H, T, T), (T, H, H), (H, T, H), (H, H, T), (H, H, H)\}$. Let A be the event of exactly 2 tails. Let B be the event that the first 2 tosses are tails. Let C be the event that all 3 tosses are tails. Write out the possible outcomes for each of these 3 events

Solution.

Example

Start with a standard deck of 52 cards and remove all the hearts and all the spades, leaving 13 red and 13 black cards. List the cards in each of the following sets:

- $N =$ not a face card

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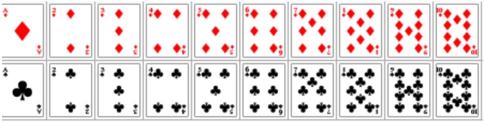

- $R =$ neither red nor an ace

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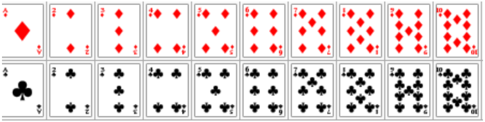

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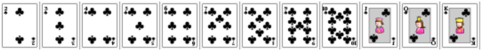

- $E =$ either black, even, or a Jack

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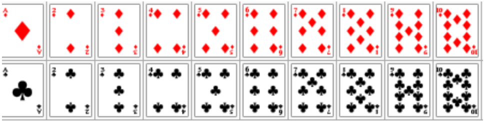

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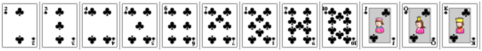

- E = either black, even, or a Jack

{Ace,2,3,4,5,6,7,8,9,10,Jack, Queen, King, 2,4,6,8,10,Jack}

Example

Suppose a fair six–sided die is rolled twice. Determine the number of possible outcomes

1. For this experiment
2. The sum of the two rolls is 5
3. The two rolls are the same
4. The sum of the two rolls is an even number

Solution.

Frequentist Interpretation of Probability

The probability of an event is the long–run proportion of times that the event occurs in independent repetitions of the random experiment. This is referred to as an empirical probability and can be written as

$$P(event) = \frac{\text{number of times that event occurs}}{\text{number of random experiment}}$$

Equally Likely Framework

$$P(event) = \frac{\text{number of outcomes for the event}}{\text{number of all possible outcomes}}$$

Remark:

- Any individual outcome of the sample space is equally likely as any other outcome in the sample space.
- In an equally likely framework, the probability of any event is the number of ways the event occurs divided by the number of total events possible.

Example

Find the probabilities associated with parts 2–4 of the previous example

Solution.

- The probability that the sum of the two rolls is 5:

Example

Find the probabilities associated with parts 2–4 of the previous example

Solution.

- The probability that the sum of the two rolls is 5: $\frac{4}{36} = \frac{1}{9}$
- The probability that the two rolls are the same:

Example

Find the probabilities associated with parts 2–4 of the previous example

Solution.

- The probability that the sum of the two rolls is 5: $\frac{4}{36} = \frac{1}{9}$
- The probability that the two rolls are the same: $\frac{6}{36} = \frac{1}{6}$
- The probability that the sum of the two rolls is an even number:

Example

Find the probabilities associated with parts 2–4 of the previous example

Solution.

- The probability that the sum of the two rolls is 5:
  $\frac{4}{36} = \frac{1}{9}$
- The probability that the two rolls are the same:
  $\frac{6}{36} = \frac{1}{6}$
- The probability that the sum of the two rolls is an even number:
  $\frac{18}{36} = \frac{1}{2}$

Probability Rules

1. Any probability must be between 0 and 1 inclusively
2. The sum of the probabilities for all the experimental outcomes must equal 1

If a probability model satisfies the two rules above, it is said to be legitimate

Example

An experiment with three outcomes has been repeated 50 times, and it was learned that outcome 1 occurred 20 times, outcome 2 occurred 13 times, and outcome 3 occurred 17 times. Assign probabilities to the outcomes. What method did you use?

Solution.

Example

A decision maker subjectively assigned the following probabilities to the four possible outcomes of an experiment:

$$P(E_1) = 0.1 \; P(E_2) = 0.15 \; P(E_3) = 0.4 \; P(E_4) = 0.2$$

Are these probability assignments legitimate? Explain.

Solution.

Independence: A Motivating Example

Example

You toss a fair coin and it comes up “Heads" three times. What is the chance that the next toss will also be a “Head"?

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Independence and Conditional Probability

Conditional Probability

Let A and B be events. The probability that event B occurs given (knowing) that event A occurs is called a conditional probability and is denoted by $P(B|A)$. The formula of conditional probability is

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

Independent events

Suppose $P(A) > 0,\ P(B) > 0$. We say that event B is independent of event A if the occurrence of event A does not affect the probability that event B occurs.

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

Summary

In this lecture, we learned

- **Some definitions**: Outcome, Event, Sample Space
- The Frequentist Interpretation of Probability and the Equally Likely Framework
- Probability Rules
- Independence and Conditional Probability