Class 11

Daniel B. Rowe, Ph.D.

Department of Mathematics, Statistics, and Computer Science
Agenda:
Recap Chapter 5.3 continued
Lecture Chapter 6.1- 6.2
Go Over Exam 2.
### Table 2

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### Formula

\[
\binom{n}{x} = \frac{n!}{x!(n-x)!}
\]

Figure from Johnson & Kuby, 2012.
5: Probability Distributions (Discrete Variables)

5.3 The Binomial Probability Distribution

For $n=10$, $p=1/2$

$$P(x) = \frac{n!}{x!(n-x)!} p^x (1-p)^{n-x}$$

TABLE 2  page 713

Binomial Probabilities \( \left( \binom{n}{x} \cdot p^x \cdot q^{n-x} \right) \) (continued)

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Figure from Johnson & Kuby, 2012.
The formula for the mean $\mu$ and variance $\sigma^2$ of Binomial is

$$
\mu = \sum_{x=0}^{n} x \frac{n!}{x!(n-x)!} p^x (1-p)^{n-x}
$$

$$
= np
$$

(5.7)

$$
\sigma^2 = \sum_{x=0}^{n} (x - \mu)^2 \frac{n!}{x!(n-x)!} p^x (1-p)^{n-x}
$$

$$
= np(1-p) \quad \rightarrow \sigma = \sqrt{np(1-p)}
$$

(5.8)
5: Probability Distributions (Discrete Variables)
5.3 Mean and Standard Deviation of the Binomial Distribution

Example:
Before, using \( \mu = \sum_{x=0}^{n} [xP(x)] \), we found \( \mu = 1 \).

Now using \( \mu = np \), we get \( \mu = (2) \cdot (1/2) = 1 \).

Before, using \( \sigma^2 = \sum_{x=0}^{n} [(x - \mu)^2 P(x)] \), we found \( \sigma^2 = 1/2 \).

Now using \( \sigma^2 = np(1-p) \), we get \( \sigma^2 = (2) \cdot (1/2) \cdot (1/2) = 1/2 \).

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5: Probability Distributions (Discrete Variables)

Questions?

Homework: Chapter 5 # 15, 17, 19, 29, 31, 43, 55a,b, 63, 77, 85, 89
Lecture Chapter 6.1- 6.2
Chapter 6: Normal Probability Distributions
(Continuous Distribution)

Daniel B. Rowe, Ph.D.

Department of Mathematics,
Statistics, and Computer Science
6: Normal Probability Distributions
6.1 Normal Probability Distributions

At beginning of course we talked about types of data.

Data

- Qualitative
  - Nominal (names)
  - Ordinal (ordered)

- Quantitative
  - Discrete (gap)
  - Continuous (continuum)

  Binomial Distribution
  Normal Distribution
We discussed discrete random variables and discrete probability functions, \( P(x) \).

The most important continuous distribution is the normal distribution (p 269). Insert \( x \) and get \( f(x) \).

**Normal Probability Distribution Function:**

\[
y = f(x) = \frac{1}{\sigma \sqrt{2\pi}} e^{-\frac{1}{2} \left( \frac{x-\mu}{\sigma} \right)^2}
\]

for all \( x \) real

(6.1)
6: Normal Probability Distributions

6.1 Normal Probability Distributions

The mathematical formula for the normal distribution is (p 269):

\[ f(x) = \frac{1}{\sigma \sqrt{2\pi}} e^{-\frac{1}{2} \left( \frac{x-\mu}{\sigma} \right)^2} \]

where
\[ e = 2.718281828459046… \]
\[ \pi = 3.141592653589793… \]
\[ \mu = \text{population mean} \]
\[ \sigma = \text{population std. deviation} \]

\[ -\infty < x, \mu < +\infty \]
\[ 0 < \sigma \]

We will not use this formula.

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6: Normal Probability Distributions
6.1 Normal Probability Distributions

Properties of Normal Distribution
1. Total Area under the normal curve is 1
2. Mound shaped, symmetric about mean, extends to $\pm \infty$
3. Has a mean of $\mu$ and standard deviation $\sigma$.
4. The mean divides area in half.
5. Nearly all area within $3\sigma$ of $\mu$.

\[ f(x) = \frac{1}{\sigma \sqrt{2\pi}} e^{-\frac{1}{2} \left( \frac{x-\mu}{\sigma} \right)^2} \]

\(-\infty < x, \mu < +\infty \quad 0 < \sigma \)

Figure modified from Johnson & Kuby, 2012.
6: Normal Probability Distributions

6.1 Normal Probability Distributions

1. Symmetric about the mean.

2. mean = median = mode.

3. Mean $\mu$ & variance $\sigma^2$ completely characterize.

4. $P(\mu - \sigma < x < \mu + \sigma) = .68$

   $P(\mu - 2\sigma < x < \mu + 2\sigma) = .95$

   $P(\mu - 3\sigma < x < \mu + 3\sigma) = .99$.

5. $P(a < x < b) =$ area under curve from $a$ to $b$.

Figure modified from Johnson & Kuby, 2012.

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6: Normal Probability Distributions
6.1 Normal Probability Distributions

When we discussed random experiments such as flipping a coin or rolling a die, we described the outcomes and events.

We then discussed the probabilities of these events which consisted of probabilities of the individual outcomes.

With the discrete binomial distribution we were interested in events such as

\[ P(4 \leq x \leq 6) = P(4) + P(5) + P(6) \]
6: Normal Probability Distributions

6.1 Normal Probability Distributions

With the continuous normal distribution, we want areas.

The probability $x$ is in the interval $a$ to $b$ is in red

Shaded area: $P(a \leq x \leq b)$

Figure modified from Johnson & Kuby, 2012.
6: Normal Probability Distributions
6.1 Normal Probability Distributions

How are areas found in math?

Aside: Don’t need to know.

$$A = \int_{a}^{b} \frac{1}{\sigma \sqrt{2\pi}} e^{-\frac{1}{2} \left( \frac{x-\mu}{\sigma} \right)^2} dx$$

This can not be done analytically and can only be done through numerical integration (Calculus).

Figure modified from Johnson & Kuby, 2012.
6: Normal Probability Distributions
6.1 Normal Probability Distributions

How are we going to find areas in this class?

We find areas of the normal distribution by using the standard normal distribution and tables in the back of the book.

When $\mu=0$ and $\sigma=1$, the curve is called the “standard” normal distribution.

I will describe standard normal, then discuss finding areas.

Figure from Johnson & Kuby, 2012.
Properties of the Standard Normal Distribution:
1. Total area under the normal curve is 1.
2. The distribution is mounded and symmetric, it extends indefinitely in both directions; approaching but never touching the horizontal axis.
3. The distribution has a mean of 0 and a standard deviation of 1.
4. The mean divides the area in half, .5 on each side.
5. Nearly all the area is between $z = -3.00$ and $z = 3.00$. 
6: Normal Probability Distributions
6.2 The Standard Normal Probability Distributions

Normal distribution with population mean $\mu$ and variance $\sigma^2$.

We want to know the (red) area under the normal distribution between $x_1$ and $x_2$.

Similar to discrete probabilities adding to 1. The total area under the normal distribution is 1.
Example: Here is a normal distribution with $\mu = 5$ and $\sigma^2 = 4$.

Let’s say we want to know the red area under the normal distribution between $x_1 = 2.28$ and $x_2 = 9.28$.

What is the area under the normal distribution between these two values?
6: Normal Probability Distributions
6.2 The Standard Normal Probability Distributions

Example: Here is a normal distribution with $\mu = 5$ and $\sigma^2 = 4$.

Aside: Don’t need to know.

$$ A = \int_{2.28}^{9.28} \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2} \left( \frac{x-5}{2} \right)^2} \, dx $$

We would normally do this with numerical integration (Calculus).
Example: Here is a normal distribution with $\mu = 5$ and $\sigma^2 = 4$.

But we can’t do calculus in this class.

Someone had the idea to convert normal distribution to the “standard” normal.

Subtract $\mu$ and divide this by $\sigma$ for every value of $x$.

$$z = (x - \mu)/\sigma.$$  

Area between $x_1$ and $x_2$ is the same as area between $z_1$ and $z_2$. 

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Example: Here is a normal distribution with \( \mu = 5 \) and \( \sigma^2 = 4 \).

Area between \( x_1 \) and \( x_2 \) is the same as area between \( z_1 \) and \( z_2 \).
Example: Here is a normal distribution with $\mu = 5$ and $\sigma^2 = 4$.

If $x_1 = 2.28$ and $x_2 = 9.28$ then $z_1 = (x_1 - \mu)/\sigma$ and $z_2 = (x_2 - \mu)/\sigma$ are?
6: Normal Probability Distributions
6.2 The Standard Normal Probability Distributions

Example: Here is a normal distribution with $\mu = 5$ and $\sigma^2 = 4$.

If $x_1 = 2.28$ and $x_2 = 9.28$ then $z_1 = (x_1 - \mu)/\sigma$ and $z_2 = (x_2 - \mu)/\sigma$ are?
Example: Here is a normal distribution with $\mu = 5$ and $\sigma^2 = 4$.

We find $z_1 = -1.36$ and $z_2 = 2.14$? Do we agree with my $z$'s?
6: Normal Probability Distributions
6.2 The Standard Normal Probability Distributions

Example: Here is a normal distribution with \( \mu = 5 \) and \( \sigma^2 = 4 \).

We find \( z_1 = -1.36 \) and \( z_2 = 2.14 \)? Do we agree with my \( z \)'s?
Example: Here is a normal distribution with $\mu = 5$ and $\sigma^2 = 4$.

Area between $x_1$ and $x_2$ is same as the area between $z_1$ and $z_2$. 

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6: Normal Probability Distributions
6.2 The Standard Normal Probability Distributions

Now we can simply look up the $z$ areas in a table.

Appendix B Table 3
Page 716.

Standard normal curve $\mu = 0$ and $\sigma^2 = 1$. 

$f(z)$
6: Normal Probability Distributions

Appendix B

Table 3

Page 716

Table 3
Cumulative Areas of the Standard Normal Distribution

The entries in this table are the cumulative probabilities for the standard normal distribution \( z \) (that is, the normal distribution with mean 0 and standard deviation 1). The shaded area under the curve of the standard normal distribution represents the cumulative probability to the left of a \( z \)-value in the left-hand tail.
6: Normal Probability Distributions

Appendix B, Table 3, Page 716

This table gives us the area less than a $z$ value.

\[ P(z < z_1) = \text{Area less than } z_1. \]

We get this from Table 3.
P(z<-1.36)=Area less than -1.36.

We get this from Table 3.
Row labeled -1.3 over to column Labeled .06.
6: Normal Probability Distributions

Appendix B, Table 3, Page 717

Table 3: Cumulative Areas of the Standard Normal Distribution

The entries in this table are the cumulative probabilities for the standard normal distribution $z$ (that is, the normal distribution with mean 0 and standard deviation 1). The shaded area under the curve of the standard normal distribution represents the cumulative probability to the left of a $z$-value in the left-hand tail.

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$P(z<2.14)=\text{Area less than 2.14.}$

We get this from Table 3.
Row labeled 2.1 over to column Labeled .04.

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### 6: Normal Probability Distributions

Appendix B, Table 3, Page 716-717

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\[
P(-1.36 < z < 2.14) = P(z < 2.14) - P(z < -1.36)
\]
6: Normal Probability Distributions

Appendix B, Table 3, Page 716-717

\[ P(-1.36 < z < 2.14) = P(z < 2.14) - P(z < -1.36) \]

\[ = 0.9838 - 0.0869 \]

\[ = 0.8969 \]

Rowe, D.B.  Red Area = 0.8969
6: Normal Probability Distributions

6.2 The Standard Normal Probability Distributions

Example: Here is a normal distribution with $\mu = 5$ and $\sigma^2 = 4$.

Area between $x_1$ and $x_2$ is same as the area between $z_1$ and $z_2$. 

Rowe, D.B.
6: Normal Probability Distributions

Questions?

Homework: Chapter 6 # 7, 9, 13, 17, 19, 29, 31, 33, 41
Go over Exam 2.