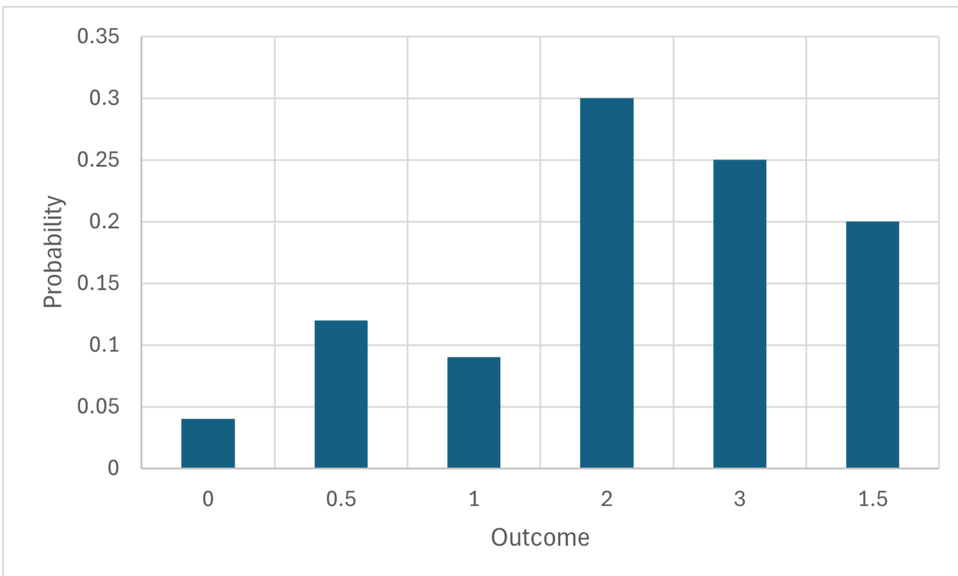
Nathan Joshua B. Sucgang
July 11, 2024

1. Suppose that X_1, X_2, X_3 are independent with common probability mass function: $P\{X_i = 0\} = .2, P\{X_i = 1\} = .3, P\{X_i = 3\} = .5, i = 1, 2, 3$

   (a) Plot the probability mass function of the average of a sample size of 2. $X_2 = \frac{X_1+X_2}{2}$

Event	X_2	**Probability**
0,0	0	0.04
0,1	0.5	0.06
1,1	1	0.09
1,3	2	0.15
3,3	3	0.25
0,3	1.5	0.1



   (b) Determine $E[X_2]$ and $Var(X_2)$

   $E[X_2] = 1.8$

   $Var(X_2) = .78$

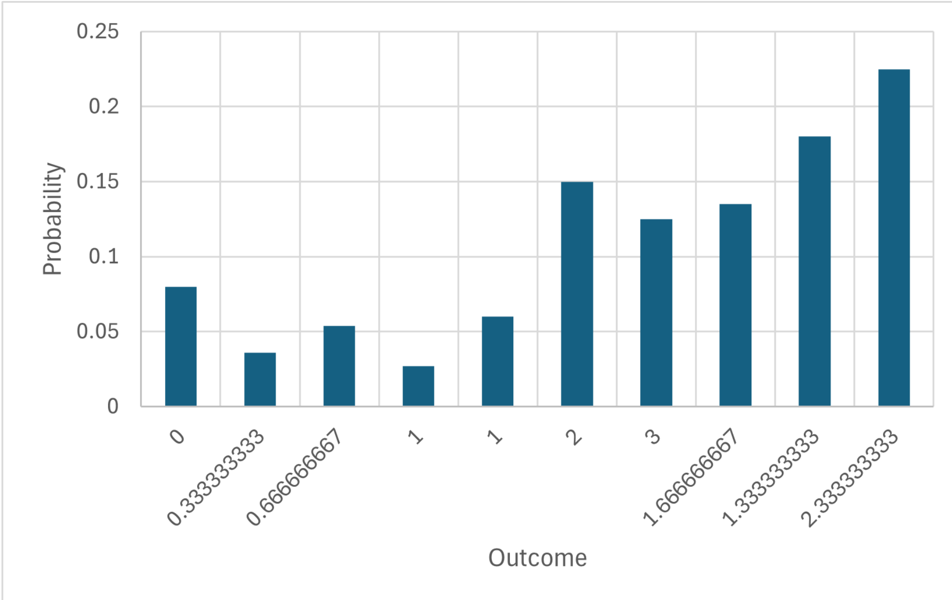
   (c) Plot the probability mass function of the average of a sample size of 3. $X_3 = \frac{X_1+X_2+X_3}{3}$

Event	X_2	**Probability**
0,0,0	0	0.08
0,0,1	0.333333333	0.036
0,1,1	0.666666667	0.054
1,1,1	1	0.027
0,0,3	1	0.06
0,3,3	2	0.15
3,3,3	3	0.125
1,1,3	1.666666667	0.135
1,3,0	1.333333333	0.18
1,3,3	2.333333333	0.225

   (d) Determine $E[X_3]$ and $Var(X_3)$

   $E[X_3] = 1.8$

   $Var(X_3) = 0.52$



2. If 10 fair dice are rolled, approximate the probability that the sum of the values obtained (which ranges from 10 to 60) is between 30 and 40 inclusive.

   Solution:

   $E[X_i] = \sum_{x_i=1}^{6} \frac{1}{6}x = \frac{7}{2}$

   $Var(X_i) = \sum_{x_i=1}^{6} \frac{1}{6}(x - \frac{7}{2})^2 = \frac{35}{12}$

   Let $X = \sum_{x_i=1}^{6} X_i$

   $E[X_i] = \sum_{x_i=1}^{10} E(X_i) = 10(\frac{7}{5}) = 35$

   $Var(X_i) = \sum_{x_i=1}^{10} Var[X_i] = 10(\frac{35}{12}) = \frac{350}{12}$

   $P(30 \le X \le 40) = P(29.5 < X < 39.5)$

   $= P\left(\frac{29.5 - 35}{\sqrt{350/12}} < \frac{X - 35}{\sqrt{350/12}} \frac{39.5 - 35}{\sqrt{350/12}}\right)$

   $= P(-1.02 \le Z \le 1.02)$

   $= 2(0.8461) - 1$

   $= 0.6922$

3. A highway department has enough salt to handle a total of 80 inches of snowfall. Suppose the daily amount of snow has a mean of 1.5 inches and a standard deviation of .3 inch.

   (a) Approximate the probability that the salt on hand will suffice for the next 50 days.

   Solution:

   Given:

$E[X_i] = 1.5$ inches
$SD[X_i] = 0.3$ inches

Let $X = \sum_{x_i=1}^{50} X_i$

$E[X] = \sum_{x_i=1}^{50} E(X_i) = 50(1.5) = 75$

$Var(X) = \sum_{x_i=1}^{50} (SD[X_i])^2 = 50(0.09) = 4.5$

$P(X \leq 80) = P\left(\frac{X - 75}{\sqrt{4.5}} < \frac{80 - 75}{\sqrt{4.5}}\right)$
$= P\left(\leq Z \leq 2.36\right)$
$= 0.9908$

(b) What assumption did you make in solving part (a)?
Solution:
It is assumed that X_i are independent and normal distributed random variables

(c) Do you think this assumption is justified? Explain briefly.
Solution:
This assumption is not justified because given snowfall in last few days is dependent on the atmospheric conditions, which would also affect today's rainfall.

4. The lifetime (in hours) of a type of electric bulb has expected value 500 and standard deviation 80. Approximate the probability that the sample mean of n such bulbs is greater than 525 when

Given:
$E[X_i] = 500$ hours
$SD[X_i] = 80$ hours

Let $\bar{X_n} = \frac{\sum_{x_i=1}^{50} X_i}{n}$

$P(\bar{X_n} > 525) = P\left(\frac{\bar{X_{25}} - 500}{80/\sqrt{n}} < \frac{525 - 500}{80/\sqrt{n}}\right)$
$= P\left(\leq Z > \sqrt{n}\frac{25}{80}\right)$
$= 1 - P\left(\leq Z = \sqrt{n}\frac{25}{80}\right)$

(a) n = 4;
$P(\bar{X_4} > 525) = 1 - P\left(\leq Z = \sqrt{4}\frac{25}{80}\right)$
$= 1 - 0.7324$
$= 0.2676$

(b) n = 16;
$P(\bar{X_1}6 > 525) = 1 - P\left(\leq Z = \sqrt{16}\frac{25}{80}\right)$
$= 1 - 0.8944 = 0.1056$

(c) n = 36;
$P(\bar{X_3}6 > 525) = 1 - P\left(\leq Z = \sqrt{36}\frac{25}{80}\right)$
$= 1 - 0.9699$
$= 0.0301$

(d) n = 64.

$P(\bar{X_6}4 > 525) = 1 - P\left(\leq Z = \sqrt{64}\frac{25}{80}\right)$
$= 1 - 0.9938$
$= 0.0062$

5. Fifty-two percent of the residents of a certain city are in favor of teaching evolution in high school. Find or approximate the probability that at least 50 percent of a random sample of size n is in favor of teaching evolution, when

Given:

$p = 0.52$

$X_i = \begin{cases} 1, & \text{if } i^{th} \text{ resident is in favour of teaching evolution,} \\ 0, & \text{otherwise} \end{cases}$

Let $X_n = \sum_{i=1}^{n} X_i$ $P\left(X_n \geq \frac{n}{2}\right) = P\left(X_n > \frac{n}{2} - 0.5\right)$

$= P\left(\frac{X_n - 0.52n}{\sqrt{0.2496n}} > \frac{n/2 - 0.5 - 0.52n}{\sqrt{0.2496n} \equiv a_n}\right)$
$= P(Z > a_n)$

(a) n = 10;
$a_{10} = \frac{10/2 - 0.5 - 0.52(10)}{\sqrt{0.2496(10)}}$
$= -0.44$
$P\left(X_n \geq \frac{n}{2}\right) = P\left(Z \leq 0.44\right)$
$= 0.6711$

(b) n = 100;
$a_{100} = \frac{100/2 - 0.5 - 0.52(100)}{\sqrt{0.2496(100)}}$
$= -0.5$
$P\left(X_n \geq \frac{n}{2}\right) = P\left(Z \leq 0.5\right)$
$= 0.6918$

(c) n = 1000;
$a_{1000} = \frac{1000/2 - 0.5 - 0.52(1000)}{\sqrt{0.2496(1000)}}$
$= -1.3$
$P\left(X_n \geq \frac{n}{2}\right) = P\left(Z \leq 1.3\right)$
$= 0.9027$

(d) n = 10,000.
$a_{10000} = \frac{10000/2 - 0.5 - 0.52(10000)}{\sqrt{0.2496(10000)}}$
$= -4.01$
$P\left(X_n \geq \frac{n}{2}\right) = P\left(Z \leq 4.01\right)$
$= .9997$

6. An electric scale gives a reading equal to the true weight plus a random error that is normally distributed with mean 0 and standard deviation $\sigma = .1$ mg. Suppose that the results of five successive weighings of the same object are as follows: $3.142, 3.163, 3.155, 3.150, 3.141$. $\bar{x} = \frac{\sum_i x_i}{n}$

$= 3.1502$

(a) Determine a 95 percent confidence interval estimate of the true weight.
$\bar{x} - z_{0.025}\sigma/\sqrt{n} \le \mu \le \bar{x} + z_{0.025}\sigma/\sqrt{n}$
$3.1502 - 1.96(0.1)/\sqrt{5} \le \mu \le 3.1502 + 1.906(0.1)/\sqrt{5}$
$3.0625 \le \mu \le 3.2379$

(b) Determine a 99 percent confidence interval estimate of the true weight.
$\bar{x} - z_{0.005}\sigma/\sqrt{n} \le \mu \le \bar{x} + z_{0.005}\sigma/\sqrt{n}$
$3.1502 - 2.58(0.1)/\sqrt{5} \le \mu \le 3.1502 + 2.08(0.1)/\sqrt{5}$
$3.0348 \le \mu \le 3.2656$

7. The following are scores on IQ tests of a random sample of 18 students at a large eastern university.
$130, 122, 119, 142, 136, 127, 120, 152, 141, 132, 127, 118, 150, 141, 133, 137, 129, 142$

if X_i's are normally distributed, $t = \dfrac{\bar{X} - \mu}{S/\sqrt{n}}$ has t distributed with $n-1$ degrees of freedom.

$\bar{x} = \dfrac{\sum_i x_i}{n}$
$= 133.22$
$s^2 = \sqrt{\dfrac{\sum_i (x_i - \bar{x})^2}{n-1}}$
$= 10.2128$

(a) Construct a 95 percent confidence interval estimate of the average IQ score of all students at the university
$\bar{x} - z_{0.025}\sigma/\sqrt{n} \le \mu \le \bar{x} + z_{0.025}\sigma/\sqrt{n}$
$133.22 - 2.11(10.2128)/\sqrt{18} \le \mu \le 133.22 + 2.11(10.2128)/\sqrt{18}$
$128.141 \le \mu \le 138.30$
$(128.141, 138.30)$

(b) Construct a 95 percent lower confidence interval estimate.
$\mu \le \bar{x} - z_{0.005}\sigma/\sqrt{n}$
$\mu \le 133.22 - 1.74(10.2128)/\sqrt{18}$
$\mu \le 129.03$
$(-\infty, 129.03)$

(c) Construct a 95 percent upper confidence interval estimate.
$\bar{x} + z_{0.025}\sigma/\sqrt{n} \le \mu$
$133.22 + 1.74(10.2128)/\sqrt{18} \le \mu$
$\mu \le 137.41$
$(137.41, \infty)$

8. The capacities (in ampere-hours) of 10 batteries were recorded as follows:
$140, 136, 150, 144, 148, 152, 138, 141, 143, 151$

(a) Estimate the population variance σ^2.
Solution:
Given:
$n = 10$
$s^2 = \sqrt{\dfrac{\sum_i (x_i - \bar{x})^2}{n-1}}$
$s^2 = 32.23$

(b) Compute a 99 percent two-sided confidence interval for σ^2.

Solution:

$(n-1)\frac{s^2}{X^2_{0.005}} \leq \sigma^2 \leq (n-1)\frac{s^2}{X^2_{0.995}}$

$9\left(\dfrac{32.23}{23.59}\right) \leq \sigma^2 \leq 9\left(\dfrac{32.23}{1.73}\right)$

$12.3 \leq \sigma^2 \leq 167.67$

$(12.3, 153.83, 167.67)$

(c) Compute a value v that enables us to state, with 90 percent confidence, that σ^2 is less than v.

Solution:

$0 \leq \sigma^2 \leq (n-1)\frac{s^2}{X^2_{0.90}}$

$0 \leq \sigma^2 \leq 9\left(\frac{32.23}{4.17}\right)$

$0 \leq \sigma^2 \leq 69.6$

9. Independent random samples are taken from the output of twomachines on a production line. The weight of each item is of interest. From the first machine, a sample of size 36 is taken, with sample mean weight of 120 grams and a sample variance of 4. From the second machine, a sample of size 64 is taken, with a sample mean weight of 130 grams and a sample variance of 5. It is assumed that the weights of items from the first machine are normally distributed with mean μ_1 and variance σ^2 and that the weights of items from the second machine are normally distributed with mean μ_2 and variance σ^2 (that is, the variances are assumed to be equal). Find a 99 percent confidence interval for $\mu_1 - \mu_2$, the difference in population means.

Solution:

Given:

$n_1 = 36$

Sample mean weight of first machine, $\bar{x_1} = 120$ grams

Sample variance of first machine, $s_1^2 = 4$

$n_2 = 64$

Sample mean weight of first machine, $\bar{x_1} = 130$ grams

Sample variance of first machine, $s_1^2 = 5$

Let $\bar{X_1}$ and $\bar{X_2}$ be the random variables corresponding to sample mean of first and second machine respectively, respectively.

$\dfrac{\bar{X_1} - \bar{X_2} - (\mu_1 - \mu_2)}{S_p\sqrt{1/n_1 + 1/n_2}} \sim t_{n_1+n_2-2}$ where

$S_p^2 = \dfrac{(n-1)(S_1)^2 + (n_2-1)(S_2)^2}{n_1 + n_2 - 2}$

$= s_p^2 = \dfrac{(n_1-1)(s_1)^2 + (n_2-1)(s_2)^2}{n_1 + n_2 - 2}]$

$= \dfrac{35(4) + 63(5)}{98}$

$= 4.643$

$s_p = 2.155$

$\left(\bar{x_1} - \bar{x_2} - t_{0.005}s_p\sqrt{1/n_1 + 1/n_2}, \bar{x_1} - \bar{x_2} + t_{0.005}s_p\sqrt{1/n_1 + 1/n_2}\right)$

$(120 - 130 - 2.627(2.155)(1/36 + 1/64), 120 - 130 + 2.627(2.155)(1/36 + 1/64))$

$(-11.18, -8.82)$

10. To estimate p, the proportion of all newborn babies that are male, the gender of 10,000 newborn babies was noted. If 5106 of them were male, determine

Solution:

Given:

$n = 10,000$

Sample probability for being a male, $\hat{p} = \dfrac{5106}{10000} = 0.5106$

(a) a 90 percent and

$(\hat{p} - z_{0.05}\sqrt{\hat{p}(1-\hat{p})/n}, \hat{p} + z_{0.05}\sqrt{\hat{p}(1-\hat{p})/n})$

$(0.5106 - 1.645\sqrt{0.5106(1-0.5106)/10000}, 0.5106 + 1.645\sqrt{0.5106(1-0.5106)/10000})$

$(0.5023, 0.5188)$

0.5106 ± 0.10

(b) a 99 percent confidence interval estimate of p.

$(\hat{p} - z_{0.05}\sqrt{\hat{p}(1-\hat{p})/n}, \hat{p} + z_{0.05}\sqrt{\hat{p}(1-\hat{p})/n})$

$(0.5106 - 2.58\sqrt{0.5106(1-0.5106)/10000}, 0.5106 + 2.58\sqrt{0.5106(1-0.5106)/10000})$

$(0.5977, 0.5235)$

$0.5106 \pm .013$