

Stat 330: Homework #6

Due on March 5, 2014 at 3:00pm

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Problem 1

Problem 4.24 from Baron.

Installation of some software package requires downloading 82 files. On the average, it takes 15 sec to download one file, with a variance of 16 sec². What is the probability that the software is installed in less than 20 minutes?

Solution

Given the problem description, we can let X be the random variable where X = number of minutes it takes to download a file. We know that $n = 82$, $\mu = 15$, $\sigma^2 = 16$, so $\sigma = 4$. Then we also know that in order to download 82 files in 20 minutes, each file must download in 0.244 minutes (or 14.6 seconds for easier understanding).

Let $S_n = X_1 + X_2 + \cdots + X_n$. Given this, we know that using the Central Limit Theorem, we can determine that given enough samples, or n , the distribution will converge to the Standard Normal. This gives us:

$$\begin{aligned} \Pr\{\text{installed in 20 minutes}\} &= \Pr\{S_n \leq 20\} \\ &= \Pr\left\{\frac{S_n - n\mu}{\sigma\sqrt{n}} \leq \frac{20 - (82)(15/60)}{(4/60)\sqrt{82}}\right\} \\ &= \Pr\{z \leq -0.828\} \\ &= \Phi(-0.828) \\ &= 0.2033 \end{aligned}$$

Problem 2

Problem 4.23 from Baron.

The lifetime of a certain electronic component is a random variable with the expectation of 5000 hours and a standard deviation of 100 hours. What is the probability that the average lifetime of 400 components is less than 5012 hours?

Solution

Let X = number of hours a component lasts. We know that $n = 400$, $\mu = 5000$, and $\sigma = 100$. Like before, we will be using the Central Limit Theorem, however, instead we are looking at the sample mean, not the S_n . We know that for the sum, $S_n \sim \text{Normal}(\text{mean} = n\mu, \text{var} = \sigma^2/n^2)$. Thus we want the mean of the sum which gives us $\bar{X} \sim \text{Normal}(\text{mean} = \mu, \text{var} = \sigma^2/n)$

Now we want the probability that \bar{X} lasts 5012 hours. This gives us:

$$\begin{aligned} \Pr\{\text{lasts 5012 hours}\} &= \Pr\{\bar{X} \geq 5012\} \\ &= \Pr\left\{\frac{\bar{X} - \mu}{\sqrt{\sigma^2/n}} \geq \frac{5012 - (5000)}{\sqrt{100^2/400^2}}\right\} \\ &= \Pr\{Z \geq 2.4\} \\ &= 1 - \Phi(2.4) \\ &= 1 - 0.0082 \\ &= 0.9918 \end{aligned}$$

Problem 3

Problem 4.28 from Baron.

Seventy independent messages are sent from an electronic transmission center. Messages are processed sequentially, one after another. Transmission time of each message is Exponential with parameter $\lambda = 5 \text{ min}^{-1}$. Find the probability that all 70 messages are transmitted in less than 12 minutes. Use the Central Limit Theorem.

Solution

Let $X \sim \text{Exponential}(\lambda)$, where $\lambda = 5 \text{ min}^{-1}$. We know that $n = 70$, $\mu = 1/\lambda$, and $\sigma^2 = 1/\lambda^2$, or $\sigma = 1/\lambda$. Once again, using the Central Limit Theorem, we want to calculate the time to transmit all n messages. Thus $S_n = X_1 + \cdots + X_n$, and letting $n \rightarrow \infty$, we get:

$$\begin{aligned} \Pr\{\text{transmits in 12 mins}\} &= \Pr\{S_n \leq 12\} \\ &= \Pr\left\{\frac{S_n - n\mu}{\sigma\sqrt{n}} \leq \frac{12 - (70)(1/5)}{(1/5)\sqrt{70}}\right\} \\ &= \Pr\{z \leq -1.20\} \\ &= \Phi(-1.20) \\ &= 0.115 \end{aligned}$$

Problem 4

In this problem, we will estimate the probability that a Geometric random variable is greater than or equal to another Geometric random variable.

Let $X \sim \text{Geometric}(p_x = 0.2)$ and $Y \sim \text{Geometric}(p_y = 0.1)$.

Part A

Get an estimate for $\Pr(X \geq Y)$ to three decimals using a simulation study. Use the R code posted (hw6prob4.R) with this part.

Solution

Our estimate based off of running the code ran is 0.3572.

Part B

Get an exact answer for $\Pr(X \geq Y)$ by using the law of total probability and the cumulative probability function for the geometric distribution. Hint:

$$\Pr(X \geq Y) = \sum_{k=1}^{\infty} \Pr(X \geq Y \mid Y = k) \Pr(Y = k) = \sum_{k=1}^{\infty} \Pr(X \geq k) \Pr_Y(k)$$

using the positive integers as a partition for Y .

Solution

Knowing that X and Y are Geometric, we know that the cdf of the distribution is $F(x) = \Pr(X \leq x) = 1 - (1 - p)^x$.

Given the hint, this becomes:

$$\begin{aligned}
 \Pr(X \geq Y) &= \sum_{k=1}^{\infty} \Pr(X = k) \Pr(Y > k) + \Pr(X = k) \Pr_Y(k) \\
 &= \sum_{k=1}^{\infty} (1 - \Pr_Y(Y > k)) \Pr(X = k) + \sum_{k=1}^{\infty} \Pr(X = k) \Pr_Y(k) \\
 &= \sum_{k=1}^{\infty} (1 - (1 - (1 - p_y)^k)) \Pr_Y(k) + \sum_{k=1}^{\infty} \Pr(X = k) \Pr_Y(k) \\
 &= \sum_{k=1}^{\infty} (1 - p_y)^k \Pr_Y(k) + \sum_{k=1}^{\infty} \Pr(X = k) \Pr_Y(k) \\
 &= \sum_{k=1}^{\infty} (1 - p_y)^k p_x (1 - p_x)^{k-1} + \sum_{k=1}^{\infty} \Pr(X = k) p_y (1 - p_y)^{k-1} \\
 &= \sum_{k=1}^{\infty} (1 - p_y)^k p_x (1 - p_x)^{k-1} + \sum_{k=1}^{\infty} p_x (1 - p_x)^{k-1} p_y (1 - p_y)^{k-1} \\
 &= \sum_{k=1}^{\infty} p_x (1 - p_y) (1 - p_y)^{k-1} (1 - p_x)^{k-1} + \sum_{k=1}^{\infty} p_x p_y (1 - p_x)^{k-1} (1 - p_y)^{k-1}
 \end{aligned}$$

By using the sum of a geometric series equation:

$$\sum_{k=1}^{\infty} r^{k-1} = 1 + r + r^2 + r^3 + \dots = \frac{1}{1 - r}$$

we get:

$$\begin{aligned}
 \Pr(X \geq Y) &= p_x (1 - p_y) [1 + (1 - p_y)^1 (1 - p_x)^1 + \dots] + p_x p_y [1 + (1 - p_y)^1 (1 - p_x)^1 + \dots] \\
 &= \frac{p_x (1 - p_y)}{1 - (1 - x)(1 - y)} \frac{p_x p_y}{1 - (1 - x)(1 - y)} \\
 &= \frac{p_x (1 - p_y) + p_x p_y}{1 - (1 - x)(1 - y)} \\
 &= \frac{p_x (1 - p_y) + p_x p_y}{p_x + p_y - p_x p_y} \\
 &= \frac{p_x - p_x p_y + p_x p_y}{p_x + p_y - p_x p_y} \\
 &= \frac{p_x}{p_x + p_y - p_x p_y}
 \end{aligned}$$

Substituting our values into the equation gives us:

$$\begin{aligned}
 \Pr(X \geq Y) &= \frac{(0.1)}{(0.1) + (0.2) - (0.1)(0.2)} \\
 &= \frac{0.1}{0.28} \\
 &= 0.3571
 \end{aligned}$$

Badda Bing, Badda Boom!

Problem 5

Suppose that a rabbit is trying to get to its home in the field. There are three places the rabbit can be: the field, the park, or the road. The rabbit starts in the park. Estimate the probability that the rabbit finds home before finding a car's tire.

A rabbit in the field will find its home with probability 0.40 and will otherwise return to the park. A rabbit in the park will find its way to the field with probability 0.80, and will go on the road with probability 0.20. A rabbit on the road will successfully get back to the park with probability 0.50. Otherwise, it won't be a good ending for the bunny.

How many rabbits will find their way to their home?

Solution

Running the R code provided, we get:

```
base::source("./hw6prob5.R")

## [1] "Results: 7621 rabbits found home, 2379 rabbits died. (Longest path was of length 35)"
## [1] "Proportion of rabbits finding home: 0.7621"
```

Thus the probability was 0.7621 which means that 7621 found their way home and the rest died.

Problem 6

Draw 100,000 random values from the sum of 12 uniform random variables values minus 6.

That is, let $U_i \sim \text{Uniform}(0, 1)$ random variables for $i = 1, 2, \dots, 12$ and let $X = U_1 + U_2 + \dots + U_{12} - 6$ such that $E[X] = 0$ and $\text{Var}[X] = 1$ and the shape of X is approximately normal. Report the portions for each number.

How do these differ from the true probabilities $\Pr(Z < z)$ for each of these cases?

Solution

Running the R code provided, we see the simulated results, the true results, and the difference in the two values:

```
base::source("./hw6prob6.R")

## [1] "Proportion under -3: 0.00104. P(Z < -3) = 0.00135. Difference: 0.00031"
## [1] "Proportion under -2: 0.02257. P(Z < -2) = 0.02275. Difference: 0.00018"
## [1] "Proportion under -1: 0.16030. P(Z < -1) = 0.15866. Difference: 0.00164"
## [1] "Proportion under 0: 0.49865. P(Z < 0) = 0.50000. Difference: 0.00135"
## [1] "Proportion under 1: 0.83823. P(Z < 1) = 0.84134. Difference: 0.00311"
## [1] "Proportion under 2: 0.97805. P(Z < 2) = 0.97725. Difference: 0.00080"
## [1] "Proportion under 3: 0.99897. P(Z < 3) = 0.99865. Difference: 0.00032"
```