

Part 1: Simulation Exercise Instructions

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Overview

In this project you will investigate the exponential distribution in R and compare it with the Central Limit Theorem. The exponential distribution can be simulated in R with `rexp(n, lambda)` where `lambda` is the rate parameter. The mean of exponential distribution is $1/\lambda$ and the standard deviation is also $1/\lambda$. Set `lambda = 0.2` for all of the simulations. You will investigate the distribution of averages of 40 exponentials. Note that you will need to do a thousand simulations.

Our results will: Illustrate via simulation and associated explanatory text the properties of the distribution of the mean of 40 exponentials. We shall:

1. Show the sample mean and compare it to the theoretical mean of the distribution.
2. Show how variable the sample is (via variance) and compare it to the theoretical variance of the distribution.
3. Show that the distribution is approximately normal.

Simulations

Question 1: Sample Mean vs Theoretical Mean

We will run a series of 1000 simulations to create a data set for comparison to theory. Each simulation will contain 40 observations and the exponential distribution function will be set to `rexp(40, 0.2)`.

Known values: `lambda = 0.2`, `n = 40`, `simulations = 1000`

```
lambda = 0.2
n = 40
nosim = 1000

set.seed(349)
```

The following code performs the simulations to collect necessary data, then plots the data:

```
exp_sim <- function(n, lambda)
{
    mean(rexp(n,lambda))
}

sim <- data.frame(ncol=2,nrow=1000)
names(sim) <- c("Index","Mean")

for (i in 1:nosim)
{
    sim[i,1] <- i
    sim[i,2] <- exp_sim(n,lambda)
}
```

Mean of n = 1000

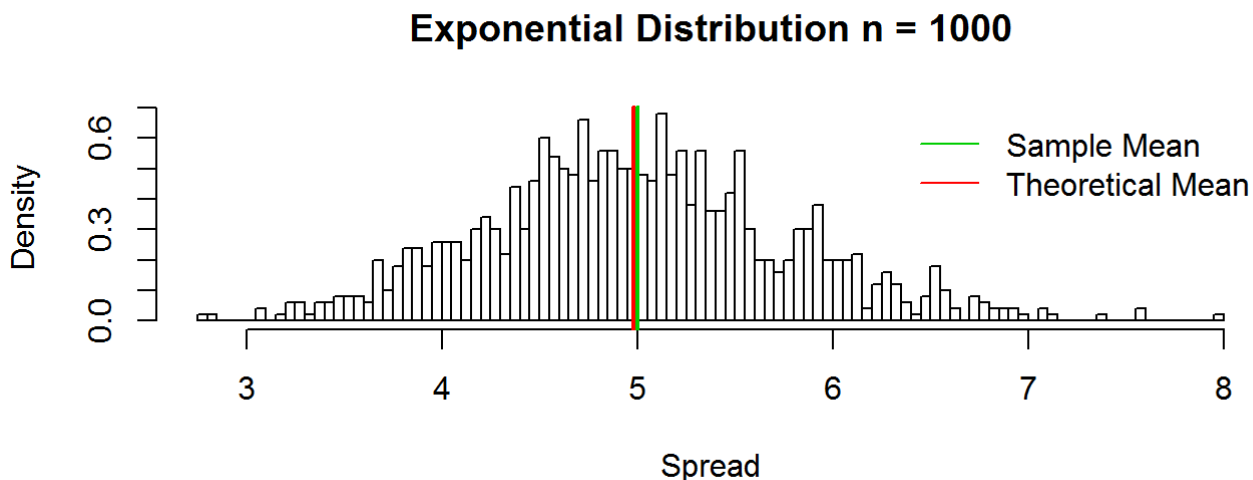
```
## [1] 4.983227
```

Theoretical exponential mean of exponential distribution

```
## [1] 5
```

The simulation mean of 4.983227 is close to the theoretical value of 5.

Histogram plot of the exponential distribution n = 1000



Question 2: Sample Variance vs Theoretical Population Variance

We now turn our attention to the variance. We will compare the variance present in the sample means of the 1000 simulations to the theoretical variance of the population.

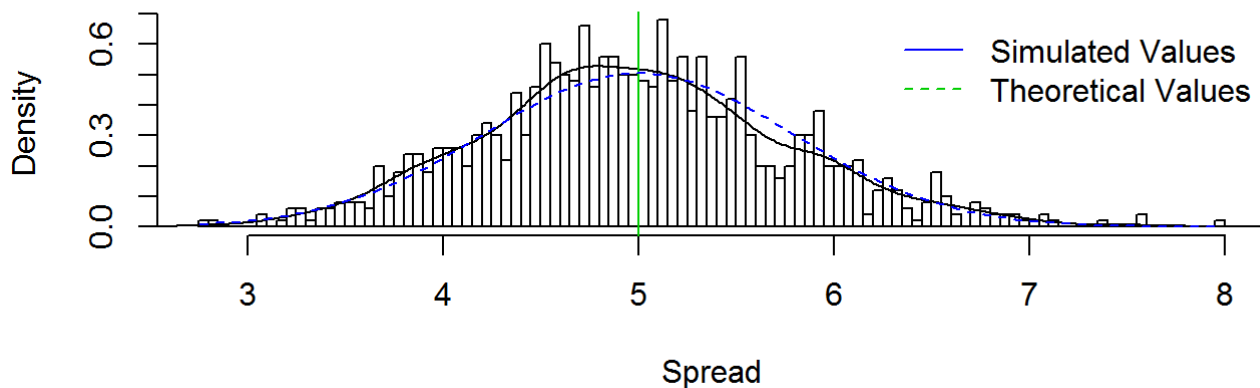
The variance of the sample means estimates the variance of the population by using the variance of the 1000 entries in the means vector times the sample size, 40.

The theoretical variance of the population.

```
## [1] 0.6010593
```

```
## [1] 0.625
```

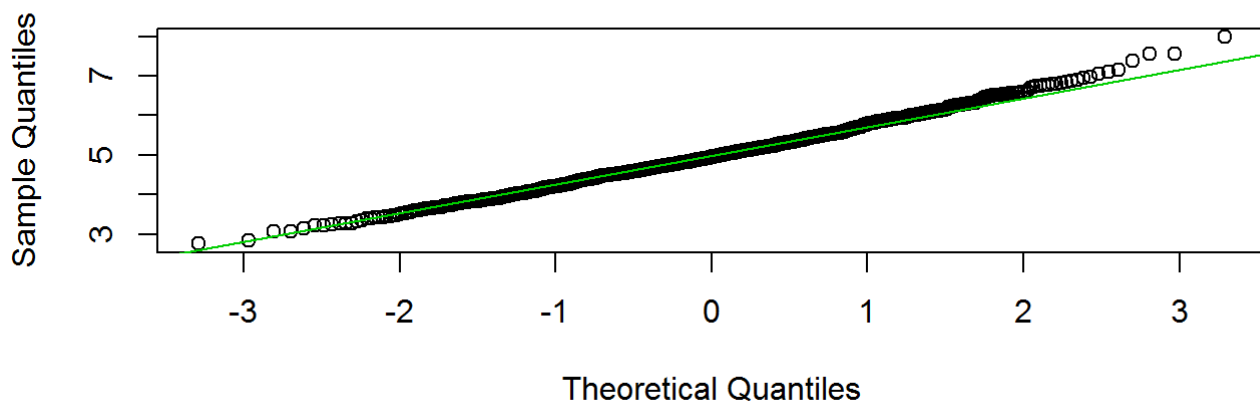
Exponential Distribution n = 1000



Question 3: Show that the distribution is approximately normal

Due to the central limit theorem, the averages of samples follow normal distribution. The figure above also shows the density computed using the histogram and the normal density plotted with theoretical mean and variance values. Also, the q-q plot below suggests the normality. The theoretical quantiles again match closely with the actual quantiles. These four methods of comparison prove that the distribution is approximately normal.

Normal Q-Q Plot



###

Conclusions

As the graph shows, we can conclude that the distribution of means of our sampled exponential distributions appear to follow a normal distribution, due to the Central Limit Theorem. If we increased our number of samples (currently 1000), the distribution would be even closer to the standard normal distribution.

Appendix

```

hist(sim$Mean,
     breaks = 100,
     prob = TRUE,
     main="Exponential Distribution n = 1000",
     xlab="Spread")
abline(v = theor_mean, col= 3,lwd = 2)
abline(v = sample_mean, col = 2,lwd = 2)
legend('topright', c("Sample Mean", "Theoretical Mean"),
     bty = "n",
     lty = c(1,1),
     col = c(col = 3, col = 2))

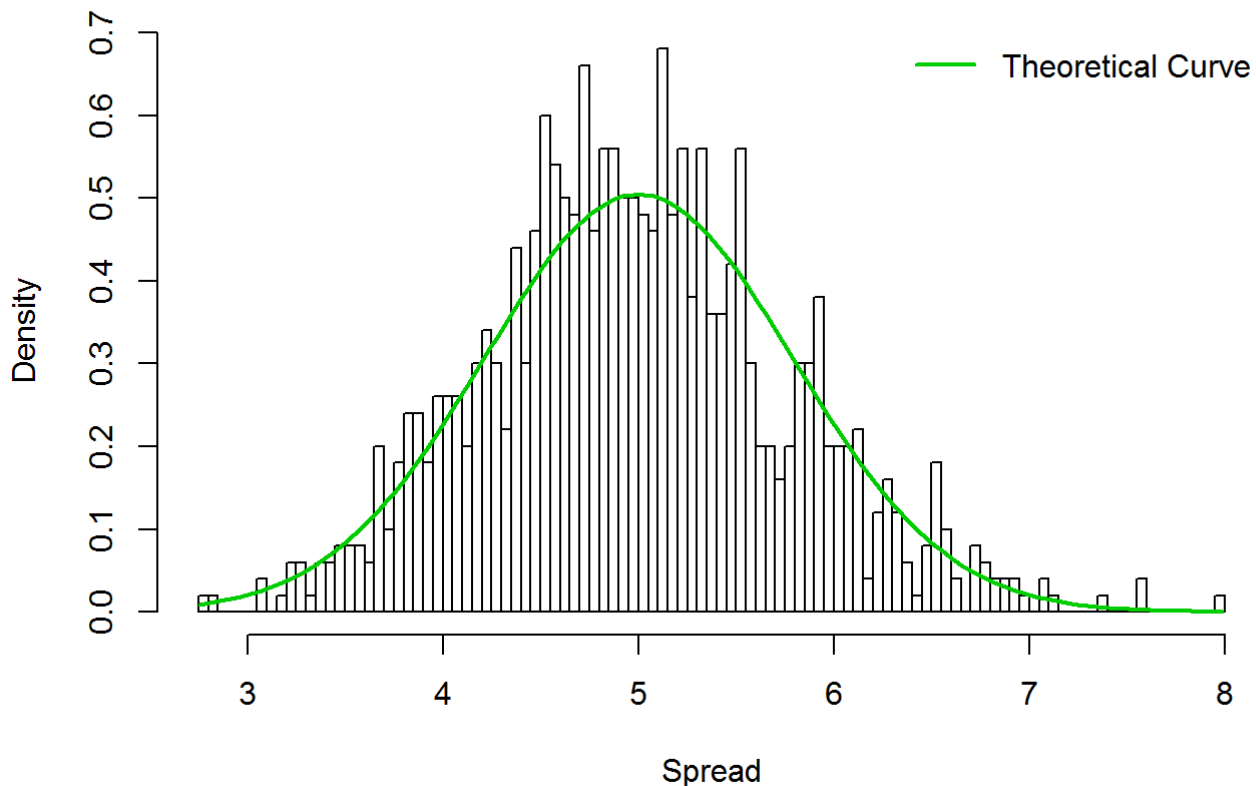
```

```

hist(sim$Mean,
     breaks = 100,
     prob = TRUE,
     main = "Exponential Distribution n = 1000",
     xlab = "Spread")
xfit <- seq(min(sim$Mean), max(sim$Mean), length = 100)
yfit <- dnorm(xfit, mean = 1/lambda, sd = (1/lambda/sqrt(40)))
lines(xfit, yfit, pch = 22, col = 3, lwd = 2)
legend('topright', c("Theoretical Curve"),
     lty = 1,lwd = 2, bty = "n", col = 3)

```

Exponential Distribution n = 1000



```
hist(sim$Mean,
      breaks = 100,
      prob = TRUE,
      main = "Exponential Distribution n = 1000",
      xlab = "Spread")
lines(density(sim$Mean))
abline(v = 1/lambda, col = 3)
xfit <- seq(min(sim$Mean), max(sim$Mean), length = 100)
yfit <- dnorm(xfit, mean = 1/lambda, sd = (1/lambda/sqrt(40)))
lines(xfit, yfit, pch = 22, col = 4, lty = 2)
legend('topright', c("Simulated Values", "Theoretical Values"),
      bty = "n", lty = c(1,2), col = c(4, 3))
```

```
qqnorm(sim$Mean,
        main = "Normal Q-Q Plot")
qqline(sim$Mean,
        col = "3")
```