

# Probability Distributions in R

# Probability Distributions

- Normal
- Binomial
- Poisson
- Uniform

# R function for Normal Distribution

R has four in built functions to generate normal distribution.

They are described below.

`rnorm(n, mean, sd)`

`dnorm(x, mean, sd)`

`pnorm(x, mean, sd)`

`qnorm(p, mean, sd)`

Following is the description of the parameters used in above functions –

- **x** is a vector of numbers.
- **p** is a vector of probabilities.
- **n** is number of observations(sample size).
- **mean** is the mean value of the sample data. It's default value is 0.
- **sd** is the standard deviation. It's default value is 1.

# The Binomial Distribution

- A Binomial Random Variable
  - $n$  identical trials
  - Two outcomes: **S**uccess or **F**ailure
  - $P(\mathbf{S}) = p$ ;  $P(\mathbf{F}) = q = 1 - p$
  - Trials are independent
  - $x$  is the number of **S**uccesses in  $n$  trials

# The Binomial Distribution-Example



- A Binomial Random Variable

- $n$  identical trials → Flip a coin 3 times
- Two outcomes: **S**uccess or **F**ailure → Outcomes are Heads or Tails
- $P(\mathbf{S}) = p$ ;  $P(\mathbf{F}) = q = 1 - p$  →  $P(H) = .5$ ;  $P(F) = 1 - .5 = .5$
- Trials are independent
- $x$  is the number of **S**'s in  $n$  trials

# The Binomial Distribution

- The Binomial Probability Distribution

$p = P(S)$  on a single trial

$q = 1 - p$

$n$  = number of trials

$x$  = number of successes

$$P(x) = \binom{n}{x} p^x q^{n-x}$$

# The Binomial Distribution

- The Binomial Probability Distribution

The number of  
ways of getting the  
desired results

The probability of  
getting the  
required number of  
successes

The probability of  
getting the  
required number of  
failures

$$P(x) = \binom{n}{x} p^x q^{n-x}$$

# The Binomial Distribution- Example

- Say 40% of the class is female.
- What is the probability that 6 of the first 10 students walking in will be female?

$$\begin{aligned}P(x) &= \binom{n}{x} p^x q^{n-x} \\&= \binom{10}{6} (.4^6) (.6^{10-6}) \\&= 210(.004096)(.1296) \\&= .1115\end{aligned}$$



# The Binomial Distribution

- A Binomial Random Variable has

Mean  $\mu = np$

Variance  $\sigma^2 = npq$

Standard Deviation  $\sigma = \sqrt{npq}$

# Example 1

What is the probability of getting 3 heads out of 6 trials  
in a coin tossing experiment

```
p <- 1/2  
choose(6,3)*(p^3)*((1-p)^(6-3))  
[1] 0.3125
```

Alternatively, we could use the *dbinom* function as  
follows:

```
dbinom(3, 6, 1/2)  
[1] 0.3125
```

# R- Binomial Distribution

R has four in-built functions to generate binomial distribution.

`rbinom(n, x, p)`

`dbinom(v, x, p)`

`pbinom(v, x, p)`

`qbinom(u, x, p)`

Following is the description of the parameters used –

- **v** is a vector of numbers.
- **u** is a vector of probabilities.
- **n** is number of observations.
- **x** is the number of trials.
- **p** is the probability of success of each trial.

# Example 2

- Calculate the probability of getting 26 or less heads from a 51 tosses of a coin.

# pbinom()

This function gives the cumulative probability of an event. It is a single value representing the probability.

# Probability of getting 26 or less heads from a 51 tosses of a coin.

```
x <- pbinom(26,51,0.5)  
print(x)
```

0.610116

# qbinom()

This function takes the probability value and gives a number whose cumulative value matches the probability value.

# If the probability of x successes is 0.25, what is the value of x.

```
x <- qbinom(0.25,51,1/2)  
print(x)
```

# Example 4

Find 8 random values from a sample of 150 with probability of 0.4

# rbinom()

This function generates required number of random values of given probability from a given sample.

# Find 8 random values from a sample of 150 with probability of 0.4.

```
x <- rbinom(8,150,.4)  
print(x)
```



# Example 5

- Hospital records show that, out of the patients suffering from a certain disease, 75% die of it. What is the probability that 6 randomly selected patients, 4 will recover?

# Example 5

Hospital records show that, out of the patients suffering from a certain disease, 75% die of it. What is the probability that 6 randomly selected patients, 4 will recover?

```
dbinom(4, 6, .25)
```

```
0.03295898
```

# Example 6

- A professional shooter finds that on the average he hits the target 4 times out of 5. If he fires 4 shots, what is the probability of
  - (a) more than 2 hits?
  - (b) at least 3 misses?

# Example 6

- a)  $1 - \text{pbinom}(2, 4, 4/5)$
- b) 3 misses means 1 hit,  
and 4 misses means 0 hits.  
 $\text{pbinom}(1, 4, 4/5)$   
0.0272

# The Poisson Distribution

- Evaluates the probability of a (usually small) number of occurrences out of many opportunities in a ...
  - Period of time
  - Area
  - Volume
  - Weight
  - Distance
  - Other units of measurement

# The Poisson Distribution

$$P(x) = \frac{\lambda^x e^{-\lambda}}{x!}$$

- $\lambda$  = mean number of occurrences in the given unit of time, area, volume, etc.
- $e = 2.71828\dots$

# The Poisson Distribution

- Say in a given stream there are an average of 3 Blackfin Tuna fishes per 100 yards. What is the probability of seeing 5 Blackfin Tuna fishes in the next 100 yards, assuming a Poisson distribution?

$$P(x = 5) = \frac{\lambda^x e^{-\lambda}}{x!} = \frac{3^5 e^{-3}}{5!} = .1008$$



# The Poisson Distribution

- How about in the next 50 yards, assuming a Poisson distribution?
  - Since the distance is only half as long, lambda is only half as large.

$$P(x=5) = \frac{\lambda^x e^{-\lambda}}{x!} = \frac{1.5^5 e^{-1.5}}{5!} = .0141$$



# Probability Calculation for poison distribution

```
> dpois(5, lambda=3)
```

# Uniform Distributions:

- A uniform distribution is used to describe equiprobable outcomes over a closed interval  $[a,b]$ . Because each outcome has the same probability, the R function `runif` is quite useful for creating a sample of random variables between some minimum and maximum value. For example, we could use the following R code to create a sample of 20 random variables in the interval between 1 and 10:
- `> runif(20,1,10)`
- `[1] 6.734666 9.334942 4.718385 9.982222 1.912516 1.865814  
2.001767 8.011947 1.643035 8.711432`
- `[11] 3.584781 7.679167 3.254184 1.273075 9.030344 6.860417  
6.125817 4.510118 3.724532 7.548615`

# Uniform Distributions:

- R also provides probability density, cumulative probability, and quantile functions for the uniform probability distribution (`dunif`, `punif`, and `qunif` respectively).

```
hist(round(runif(2000,1,10)))
```

# The Binomial Distribution

Results of 3 flips	Probability	Combined	Summary
HHH	$(p)(p)(p)$	$p^3$	$(1)p^3q^0$
HHT	$(p)(p)(q)$	$p^2q$	
HTH	$(p)(q)(p)$	$p^2q$	$(3)p^2q^1$
THH	$(q)(p)(p)$	$p^2q$	
HTT	$(p)(q)(q)$	$pq^2$	
THT	$(q)(p)(q)$	$pq^2$	$(3)p^1q^2$
TTH	$(q)(q)(p)$	$pq^2$	
TTT	$(q)(q)(q)$	$q^3$	$(1)p^0q^3$