Introduction to R

Your new data analysis software

In this class…

You will gain a *very preliminary* understanding of how to use R.

You will learn some simple functions such as linear regression.

You will *not* become an expert in using the software.

Which software do you use for data analysis?

Which software do you use for data analysis?

SO, WHY CHOOSE R?

R is an open-source software --- basically, it's FREE.

R is easy to use --- no much learning needed.

It is popular --- you can find free resources on R everywhere.

It supports machine learning.

Let's Download and install R.

Next, let's download R-Studio.

It is also free.

Data Types in R

R has several data types:

Number: 1, 2, 10.5, 100. These values can be used for calculation (e.g., addition, multiplication).

String/Character: “123”, “hello”,”MKT1000”. These values are like English words and cannot be used for calculation (here “123” is not a number).

Data Types in R

R has several data types:

Logical: It only has two values, TRUE and FASLE. You can make branch based on logical value (if TRUE, do something, if FALSE, do something else).

Integer: It means the value is an integer. In our class we don’t really use it.

You can use NA to represent missing data.

Numerical Operations

```
a = 1
b = 5
result1 = a + b^2
result2 = sqrt(b)
print(result1)
print(result2)
```

```
> a = 1
> b = 5
> result1 = a + b^2
> result2 = sqrt(b)
> print(result1)
[1] 26
> print(result2)
[1] 2.236068
```

Assigning Values

```
a = 100
b <- 100  # This is same to b = 100
print(a)
print(b)
```

Comparison

```
a = 100
b <- 100
c1 <- (a == b)  # compare if a is equal to b
print(c1)
c2 <- (a < 90) # compare if a is smaller than 90
print(c2)
c3 <- (a >= 100) # compare if a is greater than
or equal to 100
print(c3)
```

String Operations

```
a = "Big"
b = "Data"
c = 100
d1 = paste(a, b)      #concatenation
d2 = paste0(a, b)     #concatenation
d3 = toString(c)
d4 = paste0(b, c)     #transform a value to a string
print(d1)
print(d2)
print(d3)
print(d4)
```

String Operations

Note that when referring to a string, you can either put the string between ‘ and ‘, or between “ and “.

In other words, in R, ‘123’ is equivalent to “123”. Both refer to the same string.

String Operations

```
str = "Marketing and Big Data"
print(nchar(str))    #number of characters in the string
y = strsplit(str,split=' ')
#split the string when meeting a space
print(y)
z = substr(str, 2,5)
#substring from the 2nd to the 5th character
print(z)
```

List

```
vec <- c(1,3,5)
char_vec <- c("Spring", "Summer", "Autumn",
"Winter")
logic_vec <- c(TRUE, FALSE, TRUE, FALSE)
print(vec)
print(char_vec)
print(logic_vec)
```

Data Plot

```
x <- c(1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11)
y <- c(9, 7, 7, 4.5, 6, 7.8, 7, 3, 6, 2, 4)
plot(x, y)
plot(x, y, type="b")
```

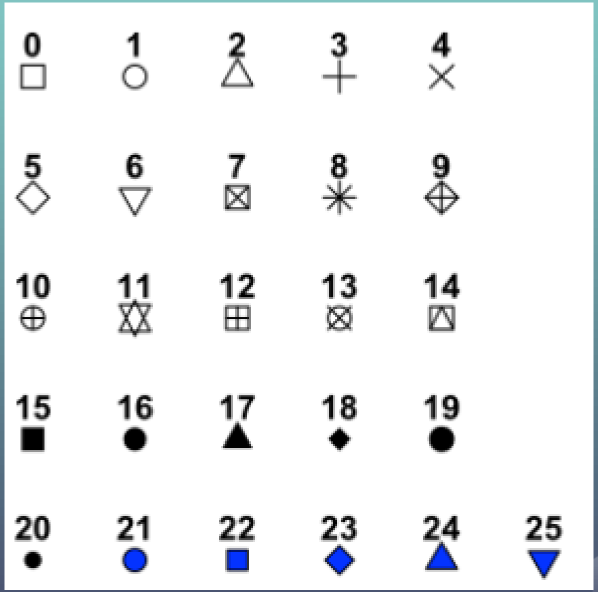
Data Plot

```
x <- c(1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11)
y <- c(9, 7, 7, 4.5, 6, 7.8, 7, 3, 6, 2, 4)
plot(x, y, pch = 17)
```

Data Plot

The “pch” code defines the appearance of your points

```
plot(x, y, pch = 17)
```



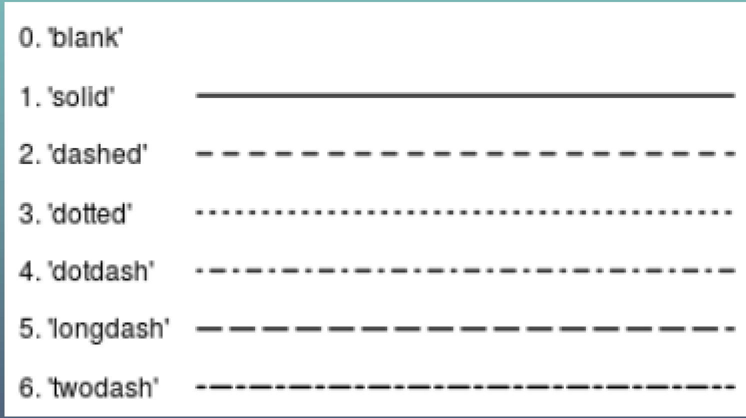
Data Plot

```
x <- c(1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11)
y1 <- c(9, 7, 7, 4.5, 6, 7.8, 7, 3, 6, 2, 4)
y2 <- c(1, 2, 4.1, 7, 5, 3, 8, 5, 6.9, 5.0, 6.3)
plot(x, y1, pch = 2, lty = 2, type="b")
lines(x, y2, pch = 1, lty = 1, type="b")
```

Data Plot

The “lty” code defines the appearance of your line

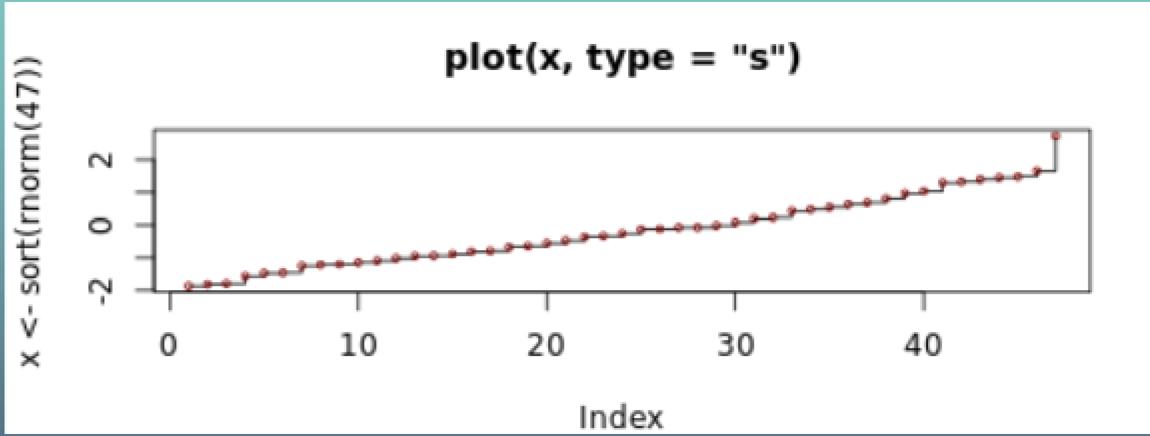
```
plot(x, y1, pch = 2,
lty = 2, type="b")
```



Data Plot

```
x <- c(1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11)
y1 <- c(9, 7, 7, 4.5, 6, 7.8, 7, 3, 6, 2, 4)
y2 <- c(1, 2, 4.1, 7, 5, 3, 8, 5, 6.9, 5.0, 6.3)
plot(x, y1, pch = 2, col = rgb(1, 0, 0), lty = 2,
type="b")
lines(x, y2, pch = 1, col = rgb(0, 1, 1), lty = 1,
type="b")
```

Data Plot



Indeed, R allows more features than we have described here. Please click here to find them out and try yourself!

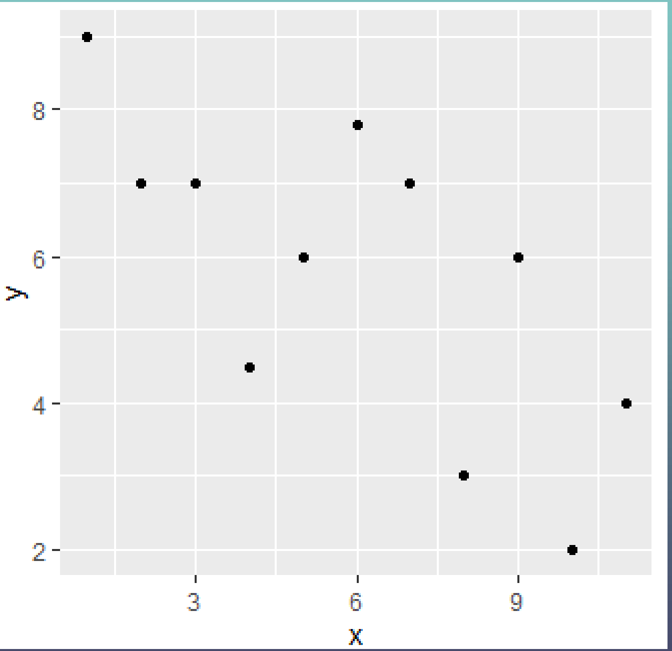
Data Plot

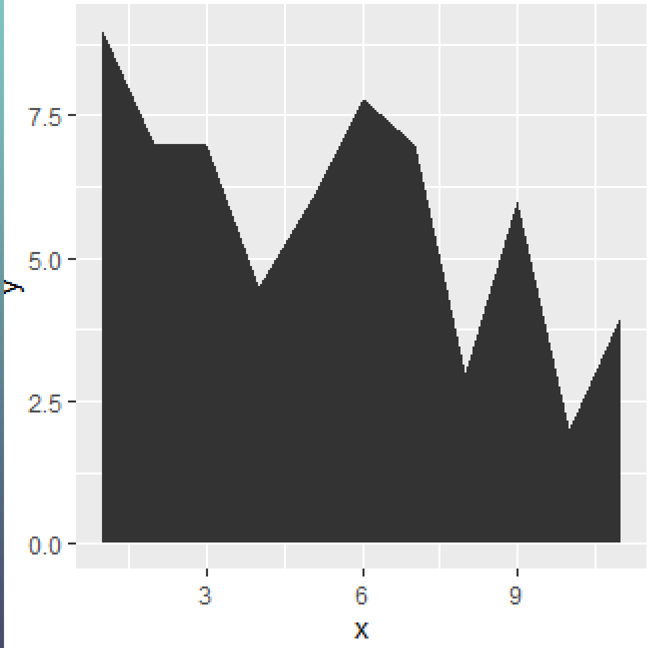
Now let's consider some advanced plotting functions. In R, we can install and use the "ggplot" package to plot nice figures.

Data Plot

```
library(ggplot2)
# create data
x <- c(1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11)
y <- c(9, 7, 7, 4.5, 6, 7.8, 7, 3, 6, 2, 4)
data <- data.frame(x, y)
# Plot
ggplot(data, aes(x, y)) + geom_point()
ggplot(data, aes(x, y)) + geom_area()
```

Data Plot

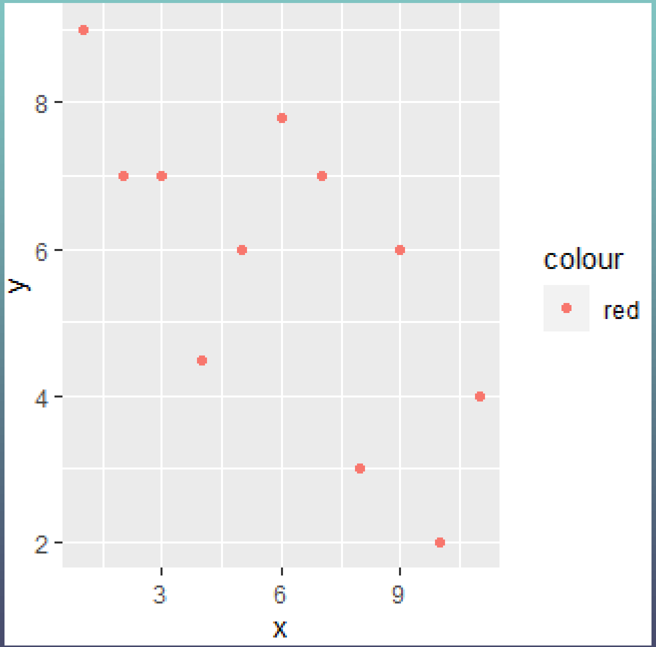


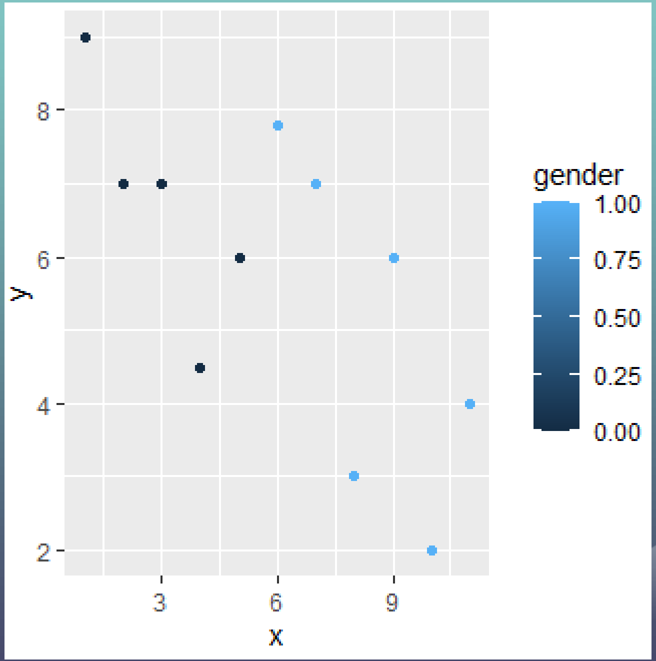


Data Plot

```
x <- c(1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11)
y <- c(9, 7, 7, 4.5, 6, 7.8, 7, 3, 6, 2, 4)
gender <- c(0, 0, 0, 0, 0, 1, 1, 1, 1, 1, 1)
data <- data.frame(x, y, gender)
ggplot(data, aes(x, y, color = 'red')) + geom_point()
figure <- ggplot(data, aes(x, y, color = gender)) +
geom_point()
```

Data Plot





Data Frame

A data frame is a list of variables of the same number of rows with unique row names, given class "data.frame".

```
employees <- data.frame(
  name = c('Alice', 'Bob', 'Carol','Denis'),
  salary = c(20000,19000,23000,22000)
  job = c('IT', 'Sales', 'Finance', 'IT' ))
```

Data Frame

You may have missing values in your data frame. In this case you can enter “NA” to represent the missing value.

```
employees <- data.frame(
  name = c('Alice', 'Bob', 'Carol','Denis'),
  salary = c(20000,NA,23000,22000),
  job = c('IT', 'Sales', NA, 'IT'))
```

Data Frame

You can use the dollar sign“$” to select a specific variable:

```
print(employees)
print(summary(employees))
print(employees$name)
```

Statistics

```
vector <- c(0, 8, 4, 6, 7, 9, 5)
print(mean(vector))
print(median(vector))
print(var(vector))        #variance
print(sd(vector))         #standard deviation
print(max(vector))        #maximum
print(min(vector))        #mimimum
print(sort(vector))       #sort the data in increasing order
```

If ... Else Operations

```
x <- 0
if (x < 0) {
  print("Negative number")
} else if (x > 0) {
  print("Positive number")
} else
  print("Zero")
```

INSTALL PACKAGES

```
> install.packages("car")
Warning in install.packages("car") :
  'lib = "C:/Program Files/R/R-4.0.4/library"' is not writable
--- Please select a CRAN mirror for use in this session ---
also installing the dependencies ‘assertthat’, ‘cpp11’, ‘digest’, ‘mime’, ‘cli’$


  There are binary versions available but the source versions are later:
             binary source needs_compilation
tidyr         1.1.2  1.1.3              TRUE
pillar        1.5.0  1.5.1             FALSE
dplyr         1.0.4  1.0.5              TRUE
MatrixModels  0.4-1  0.5-0             FALSE
```

While LOOP

```
count = 0
while (count <= 5)
{
  count = count + 1
  print(count)
}
```

For LOOP

```
vector = c(1, 3, 5, 7)
print(vector)
for (item in vector)
  print(item)
```

For LOOP (continued)

```
for (year in 2000: 2020)
  print (year)
```

```
for (year in 2000: 2020)
{
  if(year == 2008)
    next                    #skip to the next iteration
  print (year)
}
```

Functions

```
f1 <- function(a) {
  print(a + 1)
}

f1(0.5)
f1(2)
```

Functions (Continued)

```r
f2 <- function(a) {
  return(a+2)
}

print(f2(0.5))
print(f2(2))
```

Functions (Continued)

```
f3 <- function(a) {
  a <- toString(a)
  a <- paste(a, "data")
  return (a)
}

print(f3(100))
print(f3("big"))
```

Functions (Continued)

```
f4 <- function(a) {
  r1 <- a + 1
  r2 <- a + 2
  mylist <- list("r1" = r1, "r2" = r2)
  return(mylist)
}
```

```
mylist <- f4(15)
print(mylist$r1)
print(mylist$r2)
```

Generating Random Numbers

```
a = runif(1)    #generate a random number between 0 and 1
print(a)
vec = runif(5) #generate a list of 5 random numbers
print(vec)
vec = runif(3, min=0, max=100)
#generate 3 random numbers between 0 and 100
print(vec)
```

Generating Random Numbers

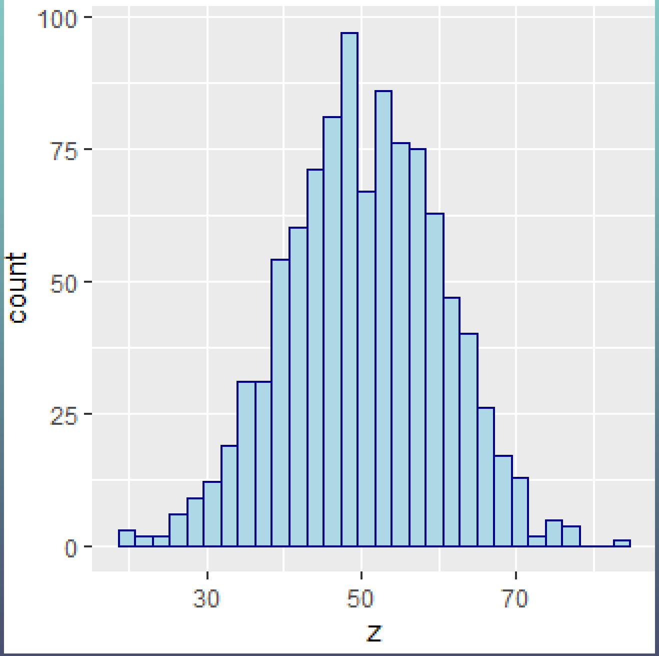
```
x = rnorm(1)
#generate a random number using the standard normal distribution
print (x)
y = rnorm(4, mean=50, sd=10)
#generate 4 random numbers following the specified normal distribibition
print (y)
z <- rnorm(1000, mean=50, sd=10)
hist(z)
#generate the histogram of z
```

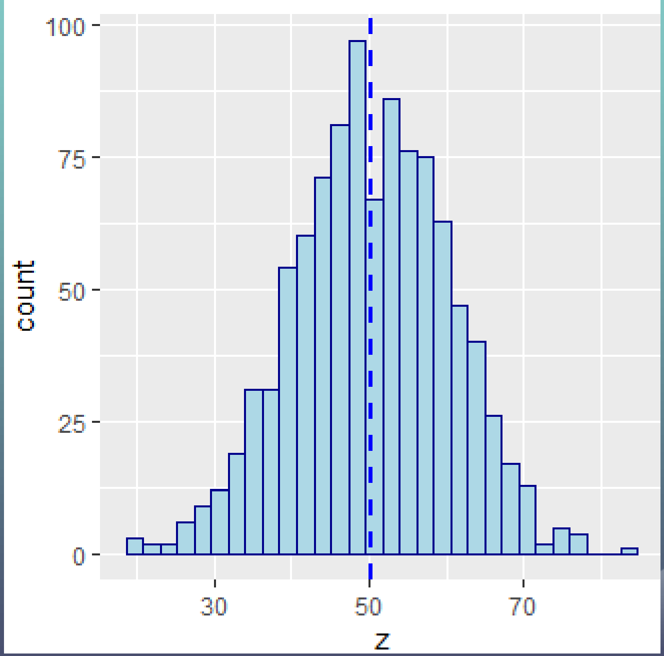
Plotting Histograms

```
library(ggplot2)
z <- rnorm(1000, mean=50, sd=10)
data <- data.frame(z)

figure <- ggplot(data, aes(z))+
  geom_histogram(color="darkblue", fill="lightblue")
figure
figure + geom_vline(aes(xintercept=mean(z)),
                       color="blue", linetype="dashed",
size=1)
```

Plotting Histograms





Directory

```
getwd()
#get working directory

setwd('C:/Users/Xi/Dropbox/Marketing Classes/Algorithm')
#set working directory
getwd()
```

Write to text files

```
file1<-file("output.txt")
writeLines(c("Big","Data"), file1)
close(file1)

file2<-file("C:/Users/Xi/Dropbox/Marketing Classes/output.txt")
writeLines(c("Big","Data"), file2)
close(file2)
```

Directory

Here, “C:/Users/Xi/Dropbox/Marketing Classes/output.txt” is the path to your txt file. You can think of it as the address of your txt file.

You can also write “C:\\Users\\Xi\\Dropbox\\Marketing Classes\\output.txt”

However, you cannot write “C:\Users\Xi\Dropbox\Marketing Classes\output.txt”.

Write to text files (Continued)

Here is another way to do this:

```
sink("output.txt")
cat("Big")
cat("\n")          #set up a new line
cat("Data")
sink()
```

Write to text files (Continued)

Now let's write a dataframe:

```
employees <- data.frame(
  name = c('Alice', 'Bob', 'Carol','Denis'),
  salary = c(20000,NA,23000,22000),
  job = c('IT', 'Sales', NA, 'IT'))
```

```
setwd('C:/Users/Xi/Dropbox/Marketing
Classes/Algorithm')
write.table(employees, file = "output.txt", sep =
"\t", row.names = FALSE)
```

Reading Data Files

R allows you to read data from various files. If you want to read a spreadsheet, you are recommended to save the file as a csv file (Comma-Separated Values), and open it with the following codes:

Untitled - R Editor

```
mydata <- read.csv("C:/Users/Xi/Dropbox/r-exercise.csv",
                   fileEncoding="UTF-8-BOM")
```

Reading Data Files

You can print the first fives rows of the data to see if it works well:

```
> head(mydata)
  Rating Expertise Votes  Purpose
1      4         6     0   couple
2      5         5     0   friend
3      5         5     0   family
4      4         4     0   family
5      4         4     0 business
6      5         5     0   family
```

Summary Statistics of the Data

To see the summary statistics of the data

```
> summary(mydata)
     Rating        Expertise         Votes              Purpose         
 Min.   :1.000   Min.   :0.000   Min.   : 0.0000   Length:180635     
 1st Qu.:4.000   1st Qu.:1.000   1st Qu.: 0.0000   Class :character  
 Median :5.000   Median :3.000   Median : 0.0000   Mode  :character  
 Mean   :4.286   Mean   :2.892   Mean   : 0.8217                     
 3rd Qu.:5.000   3rd Qu.:5.000   3rd Qu.: 1.0000                     
 Max.   :5.000   Max.   :6.000   Max.   :75.0000                     
```

Choose a Subset of Data

Suppose that we only want to use reviews with rating <= 4.

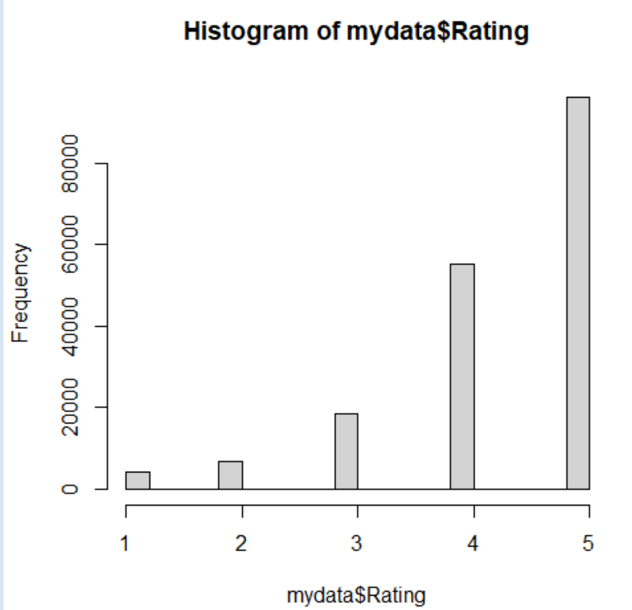
```
> subdata=subset(mydata, Rating <= 4)
> head(subdata)
   Rating Expertise Votes  Purpose
1       4         6     0   couple
4       4         4     0   family
5       4         4     0 business
7       4         3     0   family
11      4         4     0   couple
12      4         5     0   couple
```

Number of rows and columns

```
> nrow(mydata)
[1] 180635
> ncol(mydata)
[1] 4
```

Histogram

```
hist(mydata$Rating)
```



Linear Regression

Suppose that you want to do the following regression analysis:

$$\text{Rating} = a + b_1 \text{Experience}$$

```
result = lm(Rating ~ Expertise, data = mydata)
summary(result)
```

- Here “lm” stands for “linear model”.

Linear Regression

```
> summary(result)

Call:
lm(formula = Rating ~ Expertise, data = mydata)

Residuals:
    Min      1Q  Median      3Q     Max 
-3.3326 -0.3003  0.6674  0.7158  0.7642 

Coefficients:
             Estimate Std. Error t value Pr(>|t|)    
(Intercept)  4.332610   0.003872 1118.98   <2e-16 ***
Expertise   -0.016138   0.001091  -14.79   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.9531 on 180633 degrees of freedom
Multiple R-squared:  0.001209,	Adjusted R-squared:  0.001203 
F-statistic: 218.6 on 1 and 180633 DF,  p-value: < 2.2e-16
```

Linear Regression

This means you get the following result:

$$\text{Rating} = 4.332 - 0.016\ \text{Experience}$$

In addition, we get the significance value of experience (p-value) is smaller than $2 \times 10^{-16} \ll 1\%$, meaning that the coefficient at significantly different from 0. This implies that experienced reviewers give significant high ratings (to hotels).

Linear Regression

We can make predictions based on the regression output. For example, suppose we have another review with expertise 4, then you can do the followings:

```
> prediction <-  predict(result, data.frame(Expertise = 4))
> print(prediction)
      1
4.26806
```

Linear Regression

Likewise, we can also run multiple regression:

```
> result = lm(Votes ~ Expertise + Rating, data = mydata)
> summary(result)

Call:
lm(formula = Votes ~ Expertise + Rating, data = mydata)

Residuals:
   Min      1Q Median      3Q     Max 
-1.421 -0.860 -0.686  0.301 74.301 

Coefficients:
             Estimate Std. Error t value Pr(>|t|)    
(Intercept)  1.573719   0.019761  79.637   <2e-16 ***
Expertise    0.004350   0.001979   2.198    0.028 *  
Rating      -0.178399   0.004264 -41.840   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Linear Regression

Similarly, we can also make predictions based on the regression result:

```
> prediction <-  predict(result, data.frame(Expertise = 4, Rating = 2))
> print(prediction)
      1
1.23432
```

Linear Regression

Moreover, we can also run linear regression with fixed effects: Here, we take purpose as a fixed effect which takes the following values: business, couple, family, friend, solo, and unknown.

```
result = lm(Votes ~ Expertise + Rating + factor(Purpose), data = mydata)
summary(result)
```

Linear Regression

```
Coefficients:
                        Estimate Std. Error t value Pr(>|t|)    
(Intercept)             1.405531   0.020426  68.812  < 2e-16 ***
Expertise               0.004507   0.001960   2.299   0.0215 *  
Rating                 -0.180778   0.004238 -42.660  < 2e-16 ***
factor(Purpose)couple   0.176869   0.011199  15.794  < 2e-16 ***
factor(Purpose)family   0.091479   0.012095   7.564 3.94e-14 ***
factor(Purpose)friend   0.065447   0.016380   3.996 6.46e-05 ***
factor(Purpose)solo     0.081461   0.018771   4.340 1.43e-05 ***
factor(Purpose)Unknown  1.130019   0.016878  66.954  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Linear Regression

And making predictions accordingly…

```
> prediction <-  predict(result,
+ data.frame(Expertise = 4, Rating = 2, Purpose = "family"))
> print(prediction)
       1
1.153482
```

Organizing Regression Output

Suppose that we want to save the regression result in an organized matter, then we can use the “stargazer” package which can be installed on R.

```
library(stargazer)
stargazer(result, title="Regression Results",
align=TRUE, out="result.html", type = "html")
```

Regression Results

	Dependent variable:
	Votes
Expertise	0.005**
	(0.002)
Rating	-0.181***
	(0.004)
factor(Purpose)couple	0.177***
	(0.011)
factor(Purpose)family	0.091***
	(0.012)
factor(Purpose)friend	0.065***
	(0.016)
factor(Purpose)solo	0.081***
	(0.019)
factor(Purpose)Unknown	1.130***
	(0.017)
Constant	1.406***
	(0.020)
Observations	180,635
R^2	0.036
Adjusted R^2	0.036
Residual Std. Error	1.704 (df = 180627)
F Statistic	968.891*** (df = 7; 180627)
Note:	*p<0.1; **p<0.05; ***p<0.01

Organizing Regression Output

We can also contrast the regression output from different model specifications:

```
result0 = lm(Votes ~ Expertise, data = mydata)
result1 = lm(Votes ~ Expertise + Rating, data = mydata)
result2 = lm(Votes ~ Expertise + Rating + factor(Purpose), data = mydata)
stargazer(result0, result1, result2, title="Regression Results",
align=TRUE, out="result.html", type = "html")
```

Regression Results

	Dependent variable:		
	Votes		
	(1)	(2)	(3)
Expertise	0.007***	0.004**	0.005**
	(0.002)	(0.002)	(0.002)
Rating		-0.178***	-0.181***
		(0.004)	(0.004)
factor(Purpose)couple			0.177***
			(0.011)
factor(Purpose)family			0.091***
			(0.012)
factor(Purpose)friend			0.065***
			(0.016)
factor(Purpose)solo			0.081***
			(0.019)
factor(Purpose)Unknown			1.130***
			(0.017)
Constant	0.801***	1.574***	1.406***
	(0.007)	(0.020)	(0.020)
Observations	180,635	180,635	180,635
R^2	0.0001	0.010	0.036
Adjusted R^2	0.0001	0.010	0.036
Residual Std. Error	1.736 (df = 180633)	1.727 (df = 180632)	1.704 (df = 180627)
F Statistic	13.230*** (df = 1; 180633)	881.976*** (df = 2; 180632)	968.891*** (df = 7; 180627)
Note:			*p<0.1; **p<0.05; ***p<0.01

Organizing Summary Statistics

We can easily generate the summary statistics of our dataset:

```
stargazer(mydata, title="Summary Statistics",
align=TRUE, out="summary.html", type = "html")
```

Organizing Summary Statistics

Summary Statistics

Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
Rating	180,635	4.286	0.954	1	4	5	5
Expertise	180,635	2.892	2.055	0	1	5	6
Votes	180,635	0.822	1.736	0	0	1	75

Another Example of Linear Regression

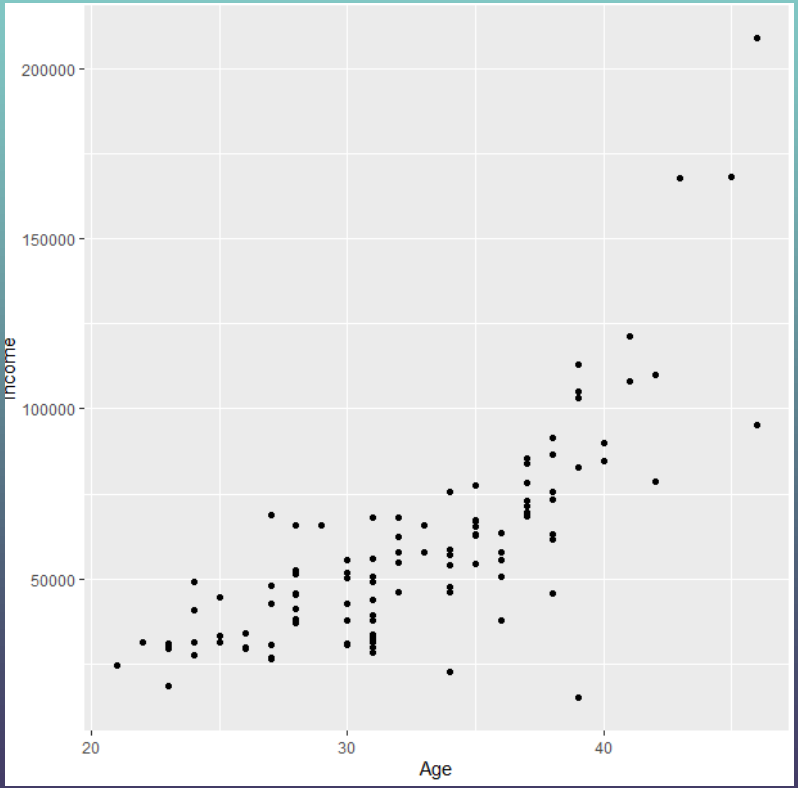
In this regression, our dataset comes from Los Angeles Neighborhoods Data. The data source is here.

It covers some basic information of several neighborhoods in Los Angeles (e.g., income, age, ethnic group, …)

Another Example of Linear Regression

```
require(ggplot2)
file = "C:/Users/Xi/Dropbox/Marketing 
Classes/Algorithm/r-exercise.txt"
mydata <- read.table(file, header = TRUE)
ggplot(mydata,aes(y=Income,x=Age))+geom_poi
nt()
```

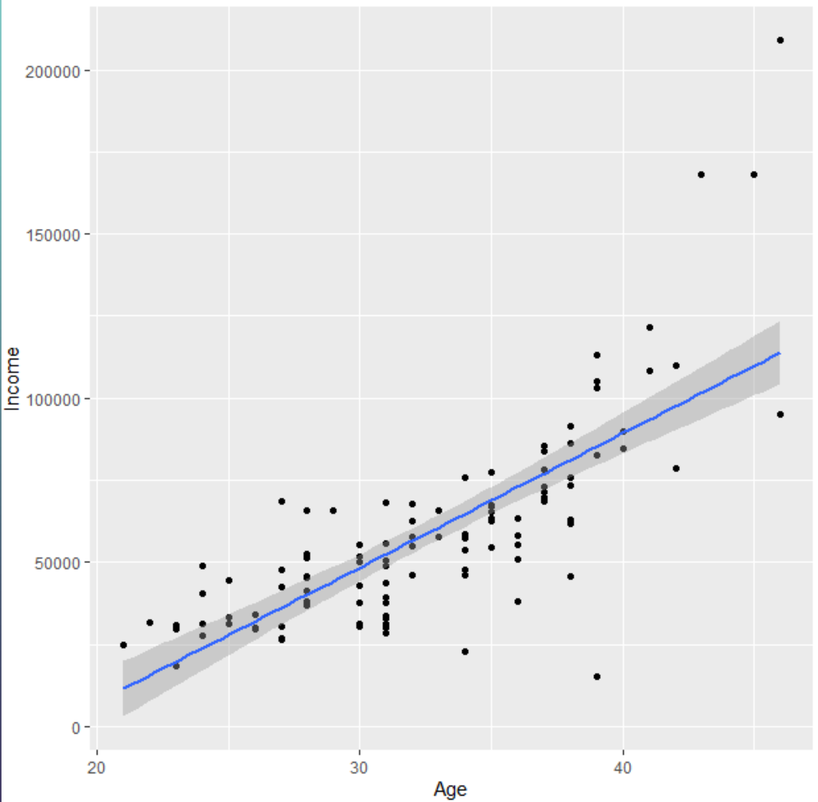
Another Example of Linear Regression



Another Example of Linear Regression

```
result <- lm(Income ~ Age, data = mydata)
summary(result)
ggplot(mydata,aes(y=Income,x=Age))+geom_poi
nt()+geom_smooth(method="lm")
```

Another Example of Linear Regression



T-test

It is very convenient to run t-tests on R:

```
x = c(1, 3, 3, 5, 3, 2, 4, 3, 5, 7)
y = c(2, 6, 3, 4, 5, 2, 5, 8, 1, 6)
t.test(x,y)
```

T-test

```
        Welch Two Sample t-test

data:  x and y
t = -0.68034, df = 16.975, p-value = 0.5055
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -2.46089  1.26089
sample estimates:
mean of x mean of y
      3.6       4.2
```

Visualize t-test

```
male <- c(18,22,21,17,20,17,23,20,22,21)
female <- c(16,20,14,21,20,18,13,15,17,21)
data        = c(mean(male), mean(female))
names(data) = c("male", "female")
se        = c(sd(male)/sqrt(length(male)),
             sd(female)/sqrt(length(female)))
windows()
bp = barplot(data, ylim=c(16, 21), xpd=FALSE)
box()
arrows(x0=bp, y0=data-se, y1=data+se, code=3, angle=90)
```

Visualize t-test