Assignment 2: Introduction to R

This assignment is an opportunity to try the R statistical package and to start to learn some of its behaviors and options.

Text like this will be general comments.

```
Text like this will be my commands to R, the R prompt is a "greater than" sign (>).
```

```
Text like this will be output from R in my examples.
```

Text like this will be problems for you to do and turn in. (There are 7 in all.)

You will need to do this (and most other) assignments on a computer with R installed. You can install it to a computer (Windows, Mac OS X, Linux) by going to the "Comprehensive R Archive Network" (CRAN) website: http://cran.us.r-project.org/. There are links to download pages for each of the above operating systems at the top of the main CRAN page.

Windows users should select the base package and then download a file with a name like R-2.x.1-win32.exe. Running this file after you download it should install R. Mac users want a file named something like R-2.x.1.dmg. Linux users will have to find a similar file under the appropriate flavor of Linux. Please note, these instructions will be written for a Windows system. While you may use Mac OS X or Linux, there may be some differences that you will be responsible for handling.

Once R is installed, start it from the desktop icon or the Start–Programs menu. However, you should use one of the available interfaces to R such as Rstudio.

To Install Rstudio follow the following steps:

Go to http://www.rstudio.com/
Click on the big `Download RStudio` button.
Click on the `Desktop` version.
On the next page click `Download Rstudio Desktop`
Under `Installers for All Platforms` get the appropriate one for yourself (i.e. Mac OS X 10.6+ 64-bit).
Open the downloaded file. It should open into a Finder window. Drag the RStudio.app icon into the alias to the `Applications` folder that is in that finder window. You can now use RStudio.

For a short introduction to R and Rstudio study the pdf files given in assignment 2
0. Assignment and basics

Assignment to an object name may be done using 1) an equals sign =, 2) a "left arrow" <- (less than, hyphen), or 3) a "right arrow" -> (hyphen, greater than).

You can type the name of any object to look at that object.

```
> n <- 15
> n
[1] 15
> a = 12
> a
[1] 12
> 24 -> z
> z
[1] 24
```

Variables must start with a letter, but may also contain numbers and periods. R is case sensitive.

```
> N <- 26.42
> N
[1] 26.42
> n
[1] 15
```

To see a list of your objects, use ls( ). The ( ) is required, even though there are no arguments.

```
> ls()
[1] "a" "n" "N" "z"
```

Use rm to delete objects you no longer need.

```
> rm(n)
> ls()
[1] "a" "N" "z"
```

You may see online help about a function using the help command or a question mark.

```
> ?ls

> help(rm)
```

Several commands are available to help find a command whose name you don't know. Note that anything after a pound sign (#) is a comment and will not have any effect on R.

```
> apropos(help)   # "help" in name
[1] ".helpForCall"   "help"           "help.search"    "help.start"
[5] "link.html.help"

> help.search("help")   # "help" in name or summary; note quotes!

> help.start()    # also remember the R Commands web page (link on
                  # class page)
```

Other data types are available. You do not need to declare these; they will be assigned automatically.

```
> name <- "Mike"  # Character data
> name
[1] "Mike"

> q1 <- TRUE            # Logical data
> q1
[1] TRUE

> q2 <- F
> q2
[1] FALSE
```

1. Simple calculation

R may be used for simple calculation, using the standard arithmetic symbols +, -, *, /, as well as parentheses and ^ (exponentiation).

```
> a <- 12+14
> a
[1] 26
> 3*5
[1] 15
> (20-4)/2
[1] 8
> 7^2
[1] 49
```

Standard mathematical functions are available.

```
> exp(2)
[1] 7.389056
> log(10)   # Natural log
[1] 2.302585
> log10(10) # Base 10
[1] 1
> log2(64)  # Base 2
[1] 6
> pi
[1] 3.141593
> cos(pi)
[1] -1
> sqrt(100)
[1] 10
```

Problem 1: Use R as a calculator to compute the following values. After you do so, cut and paste your input and output from R to Word. Add numbering in Word to identify each part of each problem. (Do this for every problem from now on.)

(a) $27(38-17)$

(b) $\ln(14^7)$

(c) $\sqrt{\frac{436}{12}}$

2. Vectors

Vectors may be created using the c command, separating your elements with commas.

```
> a <- c(1, 7, 32, 16)
> a
[1]  1  7 32 16
```

Sequences of integers may be created using a colon (:).

```
> b <- 1:10
> b
 [1]  1  2  3  4  5  6  7  8  9 10

> c <- 20:15
> c
[1] 20 19 18 17 16 15
```

Other regular vectors may be created using the seq (sequence) and rep (repeat) commands.

```
> d <- seq(1, 5, by=0.5)
> d
[1] 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0

> e <- seq(0, 10, length=5)
> e
[1]  0.0  2.5  5.0  7.5 10.0

> f <- rep(0, 5)
> f
[1] 0 0 0 0 0

> g <- rep(1:3, 4)
> g
 [1] 1 2 3 1 2 3 1 2 3 1 2 3

> h <- rep(4:6, 1:3)
> h
[1] 4 5 5 6 6 6
```

Random vectors can be created with a set of functions that start with r, such as rnorm (normal) or runif (uniform).

```
> x <- rnorm(5)   # Standard normal random variables
> x
[1] -1.4086632  0.3085322  0.3081487  0.2317044 -0.6424644

> y <- rnorm(7, 10, 3)  # Normal r.v.s with mu = 10, sigma = 3
> y
[1] 10.407509 13.000935  8.438786  8.892890 12.022136  9.817101  9.330355

> z <- runif(10)  # Uniform(0, 1) random variables
> z
```

```
 [1] 0.925665659 0.786650785 0.417698083 0.619715904 0.768478685 0.676038428
 [7] 0.050055548 0.727041628 0.008758944 0.956625536
```

If a vector is passed to an arithmetic calculation, it will be computed element-by-element.

```
> c(1, 2, 3) + c(4, 5, 6)
[1] 5 7 9
```

If the vectors involved are of different lengths, the shorter one will be repeated until it is the same length as the longer.

```
> c(1, 2, 3, 4) + c(10, 20)
[1] 11 22 13 24

> c(1, 2, 3) + c(10, 20)
[1] 11 22 13
Warning message:
longer object length
        is not a multiple of shorter object length in: c(1, 2, 3) + c(10, 20)
```

Basic mathematical functions will apply element-by-element.

```
> sqrt(c(100, 225, 400))
[1] 10 15 20
```

To select subsets of a vector, use square brackets ([ ]).

```
> d
[1] 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
> d[3]
[1] 2
> d[5:7]
[1] 3.0 3.5 4.0
```

A logical vector in the brackets will return the TRUE elements.

```
> d > 2.8
[1] FALSE FALSE FALSE FALSE  TRUE  TRUE  TRUE  TRUE  TRUE
> d[d > 2.8]
[1] 3.0 3.5 4.0 4.5 5.0
```

The number of elements in a vector can be found with the length command.

```
> length(d)
[1] 9
> length(d[d > 2.8])
[1] 5
```

Problem 2: Create the following vectors in R.

a = (5, 10, 15, 20, ..., 160)
b = (87, 86, 85, ..., 56)

Use vector arithmetic to multiply these vectors and call the result d. Select subsets of d to identify the following.

(a) What are the 19th, 20th, and 21st elements of d?
(b) What are all of the elements of d which are less than 2000?
(c) How many elements of d are greater than 6000?

3. Simple statistics

There are a variety of mathematical and statistical summaries which can be computed from a vector.

```
> 1:4
[1] 1 2 3 4

> sum(1:4)
[1] 10

> prod(1:4)       # product
[1] 24

> max(1:10)
[1] 10
> min(1:10)
[1] 1
> range(1:10)
[1]  1 10

> X <- rnorm(10)
> X
 [1]  0.2993040 -1.1337012 -0.9095197 -0.7406619 -1.1783715  0.7052832
 [7]  0.4288495 -0.8321391  1.1202479 -0.9507774

> mean(X)
[1] -0.3191486

> sort(X)
 [1] -1.1783715 -1.1337012 -0.9507774 -0.9095197 -0.8321391 -0.7406619
 [7]  0.2993040  0.4288495  0.7052832  1.1202479

> median(X)
[1] -0.7864005

> var(X)
[1] 0.739266

> sd(X)
[1] 0.8598058
```

Problem 3: Using d from problem 2, use R to compute the following statistics of d:
(a) sum
(b) median
(c) standard deviation

4. Matrices

Matrices can be created with the matrix command, specifying all elements (column-by-column) as well as the number of rows and number of columns.

```
> A <- matrix(1:12, nr=3, nc=4)
> A
     [,1] [,2] [,3] [,4]
[1,]    1    4    7   10
[2,]    2    5    8   11
[3,]    3    6    9   12
```

You may also specify the rows (or columns) as vectors, and then combine them into a matrix using the rbind (cbind) command.

```
> a <- c(1,2,3)
> a
[1] 1 2 3
> b <- c(10, 20, 30)
> b
[1] 10 20 30
> c <- c(100, 200, 300)
> c
[1] 100 200 300
> d <- c(1000, 2000, 3000)
> d
[1] 1000 2000 3000

> B <- rbind(a, b, c, d)
> B
  [,1] [,2] [,3]
a    1    2    3
b   10   20   30
c  100  200  300
d 1000 2000 3000

> C <- cbind(a, b, c, d)
> C
     a  b   c    d
[1,] 1 10 100 1000
[2,] 2 20 200 2000
[3,] 3 30 300 3000
```

To select a subset of a matrix, use the square brackets and specify rows before the comma, and columns after.

```
> C[1:2,]
     a  b   c    d
[1,] 1 10 100 1000
[2,] 2 20 200 2000
```

```
> C[,c(1,3)]
     a   c
[1,] 1 100
[2,] 2 200
[3,] 3 300
```

```
> C[1:2,c(1,3)]
     a   c
[1,] 1 100
[2,] 2 200
```

Matrix multiplication is performed with the operator %*%. Remember that order matters!

```
> B%*%C
      a      b       c       d
a    14    140    1400 1.4e+04
b   140   1400   14000 1.4e+05
c  1400  14000  140000 1.4e+06
d 14000 140000 1400000 1.4e+07
```

```
> C%*%B
        [,1]    [,2]    [,3]
[1,] 1010101 2020202 3030303
[2,] 2020202 4040404 6060606
[3,] 3030303 6060606 9090909
```

You may apply a summary function to the rows or columns of a matrix using the apply function.

```
> C
     a  b   c    d
[1,] 1 10 100 1000
[2,] 2 20 200 2000
[3,] 3 30 300 3000
```

```
> sum(C)
[1] 6666
```

```
> apply(C, 1, sum)       # sums of rows
[1] 1111 2222 3333
```

```
> apply(C, 2, sum)       # sums of columns
   a    b    c    d
   6   60  600 6000
```

Problem 4: Use R to create the following two matrices and do the indicated matrix multiplication.

$$\begin{bmatrix} 7 & 9 & 12 \\ 2 & 4 & 13 \end{bmatrix} \times \begin{bmatrix} 1 & 7 & 12 & 19 \\ 2 & 8 & 13 & 20 \\ 3 & 9 & 14 & 21 \end{bmatrix}$$

What is the resulting matrix?

4.5 Mixed modes and data frames

All elements of a matrix must be the same mode (numeric, character, logical, etc.). If you try to put different modes in a matrix, all elements will be coerced to the most general – usually character.

```
> Name <- c("Bob", "Bill", "Betty")
> Test1 <- c(80, 95, 92)
> Test2 <- c(40, 87, 90)

> grades <- cbind(Name, Test1, Test2)
> grades
     Name    Test1 Test2
[1,] "Bob"   "80"  "40"
[2,] "Bill"  "95"  "87"
[3,] "Betty" "92"  "90"
```

The solution is another complex object called a data frame. The data frame views rows as cases and columns as variables. All elements in a column must be the same mode, but different columns may be different modes.

```
> grades.df <- data.frame(Name, Test1, Test2)
> grades.df
   Name Test1 Test2
1   Bob    80    40
2  Bill    95    87
3 Betty    92    90
```

Summary functions applied to a data frame will be applied to each column.

```
> mean(grades.df)
    Name    Test1    Test2
      NA 89.00000 72.33333
Warning message:
argument is not numeric or logical: returning NA in: mean.default(X[[1]], ...)

> mean(grades.df[,2:3])
   Test1    Test2
89.00000 72.33333
```

Note: as similar as matrices and data frames appear, R considers them to be quite different. Many functions will work on one or the other, but not both. You can convert from one to the other using as.matrix or as.data.frame.

```
> C.df <- data.frame(a,b,c,d)
> C.df
  a  b   c    d
```

```
1 1 10 100 1000
2 2 20 200 2000
3 3 30 300 3000

> C.df%*%B
Error in C.df %*% B : requires numeric matrix/vector arguments
> as.matrix(C.df)%*%B
     [,1]    [,2]    [,3]
1 1010101 2020202 3030303
2 2020202 4040404 6060606
3 3030303 6060606 9090909

> C
     a  b   c    d
[1,] 1 10 100 1000
[2,] 2 20 200 2000
[3,] 3 30 300 3000

> mean(C)
[1] 555.5

> mean(as.data.frame(C))
   a    b    c    d
   2   20  200 2000
```

5. Data Import – Text Files

Data files should most easily be set up as text files with rows as cases and columns as variables. Datasets for this course will be found in this format on the course web site. Save them to a text file and use read.table to read them into R as data frames.

This will require a complete path to the file's location. The easiest way to find this is to select "Source R Code" from the file menu in R and browse to the desired file. You will get an error message, but use the up arrow or cut and paste to change the source command to read.table.

```
> iris<-read.table("C:\\...\\Iris.txt",header=T)
> iris
    Species SepalLength SepalWidth PetalLength PetalWidth
1         1         5.1        3.5         1.4        0.2
2         1         4.9        3.0         1.4        0.2
3         1         4.7        3.2         1.3        0.2
4         1         4.6        3.1         1.5        0.2
5         1         5.0        3.6         1.4        0.2
6         1         5.4        3.9         1.7        0.4
:         :          :          :           :          :
:         :          :          :           :          :
:         :          :          :           :          :
149       3         6.2        3.4         5.4        2.3
150       3         5.9        3.0         5.1        1.8

> mean(iris)
    Species SepalLength  SepalWidth PetalLength  PetalWidth
   2.000000    5.843333    3.057333    3.758000    1.199333
```

Other possible file format includes:

```
>iris<-read.table("C:\\Teaching_Advising\\sta519---Multivariate
Statistics\\08 Spring\\Data\\IRIS.csv",header=T,sep=",”)
```

Or in a handy manner:

```
> iris=read.table('clipboard')  # Copy and paste
```

Problem 5: The dataset RADIOLOGY may be found on the web page. This dataset (from problem 3.5 in your book), contains hospital information for 31 months: visits to radiology, patient-days, ER visits, and clinic visits. Save this file and use read.table to import it into R.

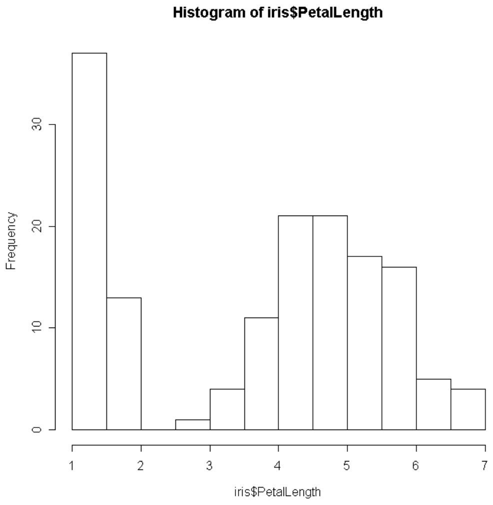
What are the means and standard deviations of the four data variables (excluding month)?

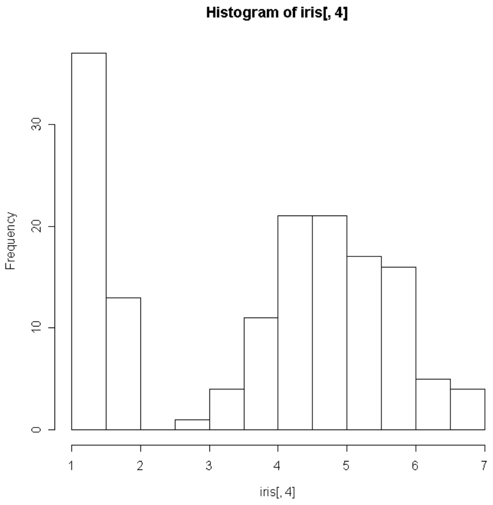
6. Graphics

R has functions to automatically plot many standard statistical graphics. Histograms and boxplots may be generated with hist and boxplot, respectively.

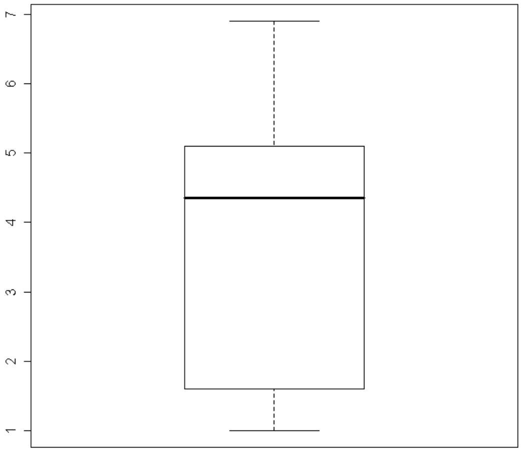
Once you have a graphic you're happy with, you can copy the entire thing. Make sure that the graphics window is the active (selected) window, and select "Copy to clipboard as bitmap" from the file menu. You can then paste your figure into Word and resize to taste.

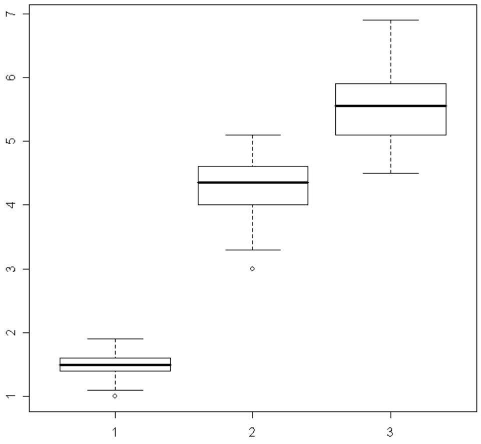
```
> hist(iris$PetalLength)
>
> hist(iris[,4])# alternative specification
```





```
> boxplot(iris$PetalLength)
> boxplot(PetalLength~Species, data=iris) # Formula description,
                                          # side-by-side boxplots
```



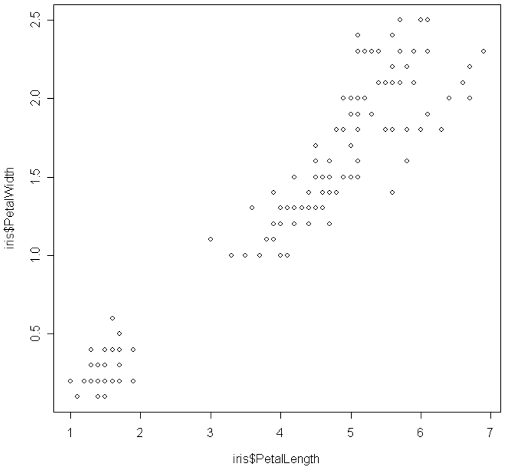


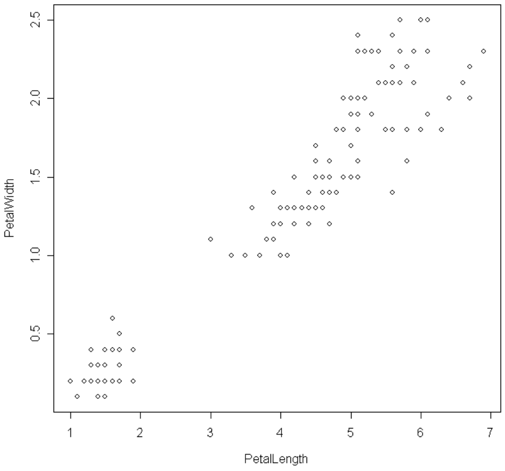
Problem 6: From the radiology data, examine the histograms and boxplots of clinic visits and radiology visits. (Note: these will be two separate boxplots, not a single side-by-side boxplot as above.)

7. Scatterplots and simple linear regression

Scatterplots may be produced by using the plot command. For separate vectors, the form is plot(x, y). For columns in a dataframe, the form is plot(yvar ~ xvar, data=dataframe).

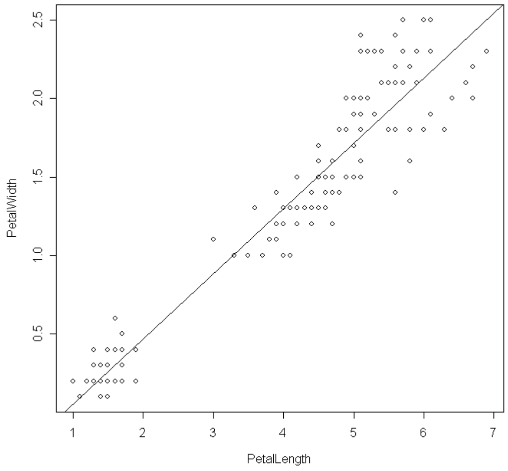
```
> plot(iris$PetalLength, iris$PetalWidth)
> plot(PetalWidth~PetalLength, data=iris)
```





Linear regression is done with the lm command, with a form similar to the second version of the scatterplot command.

```
> PetalReg <- lm(PetalWidth~PetalLength, data=iris)
> summary(PetalReg)

Call:
lm(formula = PetalWidth ~ PetalLength, data = iris)

Residuals:
     Min       1Q   Median       3Q      Max
-0.56515 -0.12358 -0.01898  0.13288  0.64272

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) -0.363076   0.039762  -9.131  4.7e-16 ***
PetalLength  0.415755   0.009582  43.387  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.2065 on 148 degrees of freedom
Multiple R-Squared: 0.9271,     Adjusted R-squared: 0.9266
F-statistic:  1882 on 1 and 148 DF,  p-value: < 2.2e-16

> abline(PetalReg)      # add the regression line to the plot
```



Problem 7: From the radiology data, construct a scatterplot of clinic visits (x) versus radiology visits (y). Perform the simple linear regression of radiology visits on clinic visits and add the regression line to the plot. Briefly comment on the fit.

Check out some misc R commands (always use **bold Courier New** font for your R commands in your homework) like:

```
> ls.str(); ls.str; ?ls.str
> ls()
> getwd()
> setwd()
> dir()
> search()
> searchpaths()
> attach()
> detach()
> history()
> save.history()
> save.image()
> demo()
> demo(package = .packages(all.available = TRUE))
> help.search()
> help.search("linear models")
> help.search(keyword = "hplot")
> help(library=car)
> library()
> demo()
> demo(package = .packages(all.available = TRUE))
```

In addition to the standard packages listed in the search,

```
> search()
```

```
".GlobalEnv"        "package:stats"     "package:graphics"
"package:grDevices" "package:utils"     "package:datasets"
"package:methods"   "Autoloads"         "package:base"
```

you also need the following for this course:

graphics

lattice

scatterplot3d

rgl

MASS

cluster

sem

rpart

randomForest

TeachingDemos

ellipse

kohonen

mclust

mvtnorm

mvtnormpcs

neural

tree

mva

graphics

lattice

scatterplot3d

amap

AMORE

ade4

nnet

car

ca

vcd