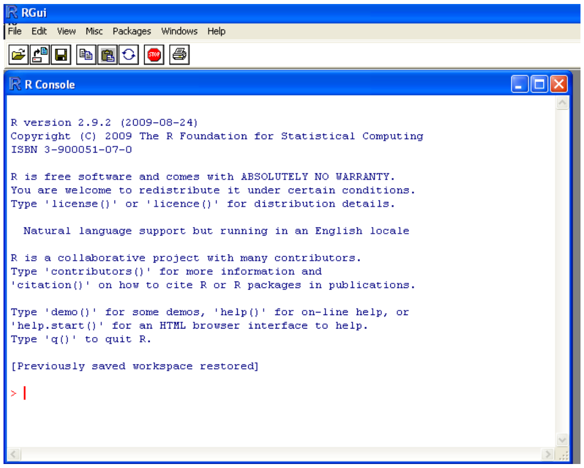
Getting started with R

This handout gives a very brief introduction to R to give you a rough idea of some basic R features. We assume that R has been installed on your computer.

Start up R

Start R by double-clicking on the R shortcut on the desktop. A window called the R **Console** will open up.



```
R version 2.9.2 (2009-08-24)
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ISBN 3-900051-07-0

R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
Type 'license()' or 'licence()' for distribution details.

  Natural language support but running in an English locale

R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

[Previously saved workspace restored]

> 
```

Type commands after the prompt > and then press the <**ENTER**> key.

Note: anything after the pound symbol # is a comment—explanatory text that is not executed.

```
> 4*9              # Simple arithmetic
[1] 36
```

If you strike the <ENTER> key before typing a complete expression, you will see the *continuation prompt*, the plus sign (+). For example, suppose you wish to calculate $3 + 2 * (8 - 4)$, but you accidentally strike the <ENTER> key after typing the 8:

```
> 3+2*(8  <ENTER>
+
```

Finish the expression by typing -4) after the +

```
+  - 4) <ENTER>
[1] 11
```

Create a sequence incrementing by 1:

```
> 20:30
[1] 20 21 22 23 24 25 26 27 28 29 30
```

We will create an object called `dog` and assign it the values 1, 2, 3, 4, 5. The symbol <- is the assignment operator.

```
> dog <- 1:5
> dog
[1] 1 2 3 4 5
> dog + 10
[1] 11 12 13 14 15
> 3*dog
[1] 3 6 9 12 15
> sum(dog)        # 1+2+3+4+5
[1] 15
```

The object `dog` is called a *vector*.

If you need to abort a command, press the escape key <**ESC**>. The up arrow key ↑ can be used to recall previous entries.

To obtain help on any of the commands, type the name of the command you wish help on:

```
> ?sum
```

Importing data

Data for the textbook can be downloaded from the web site
`https://sites.google.com/site/ChiharaHesterberg`

For instance, let's start with the Flight Delays Case Study (see Chapter 2, **Exploratory Data Analysis**, of the text for a description of this data set). For now, we assume the file `FlightDelays.csv` is on the desktop of your computer. We use the `read.csv` command to read it into our `R` session,

```
> FlightDelays <- read.csv("C:/Users/UserName/Desktop/FlightDelays.csv")
```

or on the Macintosh

```
> FlightDelays <- read.csv("Users/UserName/Desktop/FlightDelays.csv")
```

where `UserName` is the name used to login to this session.

To view the names of the variables in `FlightDelays`:

```
> names(FlightDelays)
```

To view the first part of the data, use the `head` command:

```
> head(FlightDelays)
```

(What do you suppose the `tail` command does?)

The columns are the *variables*. There are two types of variables: *numeric*, for example, FlightLength and Delay and *factor* (also called *categorical*) (for example Carrier and DepartTime). The rows are called *observations* or *cases*.

To check the size (dimension) of the data frame, type

```
> dim(FlightDelays)
[1] 4029  10
```

This tells us that there are 4029 observations and 10 columns.

Tables, bar charts and histograms

The factor variable Carrier in the **FlightDelays** data set assigns each flight to one of two *levels*: UA or AA. To obtain the summary of this variable

```
> table(FlightDelays$Carrier)
  AA   UA
2906 1123
```

Remark: R is *case-sensitive*! Carrier and carrier are considered different.

To visualize the distribution of a factor variable, create a *bar chart*:

```
> barplot(table(FlightDelays$Carrier))
```

To compare two categorical variables, the airline (Carrier) and whether or not the flight was delayed by more than 30 minutes (Delayed30):

```
> table(FlightDelays$Carrier, FlightDelays$Delayed30)

         Delayed30
Carrier   No  Yes
     AA 2513  393
     UA  919  204
```

To see the distribution of a numeric variable, create a histogram.

```
> hist(FlightDelays$Delay)
```

The shape of the distribution of this variable is *right-skewed*.

Numeric Summaries

Because it is a bit cumbersome to use the syntax FlightDelays$Delay each time we want to work with the Delay variable, we will create a new object delay:

```
> delay <- FlightDelays$Delay
> mean(delay)
> median(delay)
```

To compute the *trimmed* mean, trimming by 25% on either side,

```
> mean(delay, trim = .25)
```

Other basic statistics:

```
> max(delay)
> min(delay)
> range(delay)
> var(delay)            #variance
> sd(delay)             #standard deviation
> quantile(delay)       #quartiles
```

If you need the population variance (that is, denominator of 1/n instead of 1/(n-1)),

```
> n <- length(delay)
> (n-1)/n*var(delay)
```

The `tapply` command

The `tapply` command allows you to compute numeric summaries on values based on levels of a factor variable. For instance, find the mean flight delay length by carrier,

```
> tapply(delay, FlightDelays$Carrier, mean)
```

or the median flight delay length by time of departure

```
> tapply(delay, FlightDelays$DepartTime, median)
```

Boxplots

Boxplots give a visualization of the 5-number summary of a variable.

```
> summary(delay)          #numeric summary
> boxplot(delay)
```

To compare the distribution of a numeric variable across the levels of a factor variable

```
> tapply(delay, FlightDelays$Day, summary)
> boxplot(Delay ~ Day, data = FlightDelays)
> tapply(delay, FlightDelays$DepartTime, summary)
> boxplot(Delay ~ DepartTime, data = FlightDelays)
```

The `boxplot` command gives the option of using a formula syntax, `Numeric` $\sim$ `Factor`. In this case, you do not need to use the $ syntax if you specify the data set.

Misc. Remarks

- Functions in R are called by typing their name followed by arguments surrounded by *parentheses*: ex. hist(delay). Typing a function name without parentheses will give the code for the function.

  ```
  > sd
  ```

- We saw earlier that we can assign names to data (we created a vector called dog.) Names can be any length, must start with a letter, and may contain letters or numbers:

  ```
  > fish25 <- 10:35
  > fish25
  ```

  Certain names are **reserved** so be careful to not use them: cat, c, t, T, F,...

  To be safe, before making an assignment, type the name:

  ```
  > whale
  [1] Problem: Object "whale" not found
  ```

  Safe to use whale!

  ```
  > whale <- 200
  > objects()
  > rm(whale)
  > objects()
  ```

- In general, R is space-insensitive.

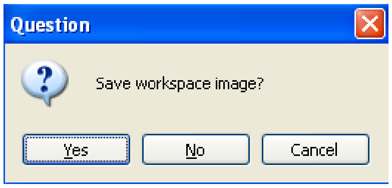
  ```
  > 3 +4
  > 3+   4
  > mean(3+5)
  > mean ( 3 + 5 )
  ```

  BUT, the assignment operator must not have spaces! <- is different from <   -

- To quit, type

  ```
  > q()
  ```

  You will be given an option to **Save the workspace image**.



Save workspace image?

Select **Yes**: all objects created in this session are saved to your working directory so that the next time you start up R, if you load this working directory, these objects will still be available. You will not have to re-import FlightDelays, for instance, nor recreate delay.

You can, for back-up purposes, save data to an external file/disk by using, for instance, the write.csv command. See the help file for more information.

Workspace Management

It will be convenient to set up a folder to store the data for this textbook. In the directory where you keep your document, create a folder called R and then a subfolder called **MathStats**. The full path depending on the operating system (PC or Mac) will look something like

C:\Users\UserName\Documents\R\MathStats,

or

Users\UserName\Documents\R\MathStats.

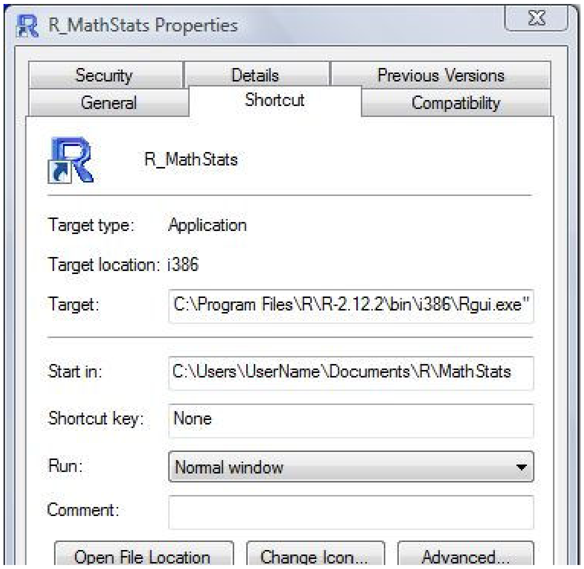
(the exact path will depend on your computer's particular configuration).

Next, we will set up R to start in the above directory.

Windows

On the desktop of your PC, find the R shortcut, right-click and from the context menu, select **Properties**. In the **Start In:** field, type the path to this folder, for instance

`C:\Users\UserName\Documents\R\MathStats`



R_MathStats

Target type: Application

Target location: i386

Target: C:\Program Files\R\R-2.12.2\bin\i386\Rgui.exe"

Start in: C:\Users\UserName\Documents\R\MathStats

Shortcut key: None

Run: Normal window

Comment:

and then click **OK**.

Starting R by clicking on this short-cut will automatically load the **MathStats** working directory. To check this,

```
> getwd()
[1] "C:/Users/UserName/Documents/R/MathStats"
```

Copy data files to the working directory. To read them into your R session, you then only need to type the name of the file, rather than a long path. For instance, to read in the data for the Flight Delays Case Study,

```
> FlightDelays <- read.csv("FlightDelays.csv")
```

Rename your shortcut (say to **R.MathStats**) since you may want to set up different working directories for different projects and classes.

Macintosh

On the Macintosh, dragging the **MathStats** folder icon onto the R icon will start R in the **MathStats** working directory.

Alternatively, if R is already running, then at the menu, under **R** > **Preferences**, click on **Start-up**. You can change the default working directory to be the **MathStats** folder. Then R will always start with the **MathStats** being the working directory.

Copy data files to the working directory. To read them into your R session, you then only need to type the name of the file, rather than a long path. For instance, to read in the data for the Flight Delays Case Study,

```
> FlightDelays <- read.csv("FlightDelays.csv")
```

RStudio

RStudio is an integrated development environment for R. It is free and can be obtained from http://www.rstudio.org. **RStudio** runs on Windows, Macs and Linux. It has a nice interface for managing different projects and workspaces.

Vectors in R

The basic data object in R is the vector. Even scalars are vectors of length 1.

There are several ways to create vectors.

The : operator creates sequences incrementing/decrementing by 1.

```
> 1:10
> 5:-3
```

The seq() function creates sequences also.

```
> seq(0, 3, by = .2)
> seq(0, 3, length = 15)
> quantile(delay, seq(0, 1, by = .1))     #deciles of delay
```

To create vectors with no particular pattern, use the `c()` function (`c` for **c**ombine).

```
> c(1, 4, 8, 2, 9)
> x <- c(2, 0, -4)
> x
> c(x, 0:5, x)
```

For vectors of characters,

```
> c("a", "b", "c", "d")
```

or logical values (note that there are no double quotes):

```
> c(T, F, F, T, T, F)
```

The `rep()` command for repeating values:

```
> rep("a", 5)
> rep(c("a", "b"), 5)
> rep(c("a", "b"), c(5, 2))
```

The “class” attribute

Use `data.class` to determine the class attribute of an object.

```
> state.name
> data.class(state.name)
> state.name == "Idaho"
> data.class(state.name == "Idaho")
> head(FlightDelays$Carrier)
> data.class(FlightDelays$Carrier)
```

Basic Arithmetic

```
> x <- 1:5
> x - 3
> x*10
> x/10
> x^2
> 2^x
> log(x)

> w <- 6:10
> w
> x*w                 #coordinate-wise multiplication
```

Logical expressions

```
> x < 3
> x == 4
```

Subsetting

In many cases, we will want only a portion of a data set. For subsetting a vector, the basic syntax is `vector[`*index*`]`. In particular, note the use of *brackets* to indicate that we are subsetting.

```
> z <- c(8, 3, 0, 9, 9, 2, 1, 3)
```

The fourth element of `z`:

```
> z[4]
```

The first, third and fourth element,

```
> z[c(1, 3, 4)]
```

All elements *except* the first, third and fourth:

```
> z[-c(1, 3, 4)]
```

To return the values of `z` less than 4, we first introduce the `which` command:

```
> which(z < 4)             # which positions are z values < 4?
> index <- which(z < 4)    # store in index
> z[index]                 # return z[c(2, 3, 6, 7)]
```

The `subset` command

The `subset` command is used to extract rows of the data that satisfy certain conditions.

If necessary, re-import the `FlightDelays` data set.

Recall that we extracted the variable `delay` using the $ syntax:

```
> delay <- FlightDelays$Delay
```

The `subset` command can also be used:

```
> delay <- subset(FlightDelays, select = Delay, drop = TRUE)
```

The `select =` argument indicates which column to choose.

The `drop = TRUE` argument is need to create a `vector`. Compare the output of

```
> subset(FlightDelays, select = Delay, drop = TRUE)
```

to

```
> subset(FlightDelays, select = Delay)
```

The second output (omitting the `drop = TRUE` argument) is a `data.frame` object (more on data frames later).

Suppose you wish to extract the flight delay lengths for all days except Monday and then find the mean delay length:

```
> delay2 <- subset(FlightDelays, select = Delay, subset = Day != "Mon",
  drop = TRUE)
> mean(delay2)
```

The `subset =` argument is a logical expression indicating which rows to keep. We want those days not equal to Monday.

To extract the delay lengths for Saturday and Sunday only

```
> delay3 <- subset(FlightDelays, select = Delay,
  subset = (Day == "Sat" | Day == "Sun"), drop = TRUE)
> mean(delay3)
```

The vertical bar | stands for "or."

Suppose you want to find those observations when the delay length was greater than the mean delay length. We'll store this in a vector called `index`.

```
> index <- which(delay > mean(delay))
> head(index)
[1]  2 10 12 14 15 16
```

Thus, observations in rows 2, 10, 12, 14, 15, 16 are the first six that correspond to flights that had delays that were larger than the average delay length.

Vectorized operators

==	equal to
!=	not equal to
>	greater than
>=	greater than or equal to
<	less than
<=	less than or equal to
&	vectorized AND
|	vectorized OR
!	not

Programming Note: The vectorized AND and OR are for use with vectors (when you are extracting subsets of vectors). For control in programming (ex. when writing `for` or `if` statements), the operators are && and ||.

Misc. commands on vectors

```
> length(z)       # number of elements in z
> sum(z)          # add elements in z
> sort(z)         # sort in increasing order
```

The `sample` command is used to obtain random samples from a set.

For instance, to permute the numbers $1, 2, \cdots, 10$:

```
> sample(10)
```

To obtain a random sample from $1, 2, \cdots, 10$ of size 4 (without replacement):

```
> sample(10, 4)
```

Without replacement is the default; if you want to sample with replacement:

```
> sample(10, 4, replace = TRUE)
```

The built-in vector `state.name` contains the 50 states.

```
> state.name
```

Draw a random sample of 20 states:

```
> sample(state.name, 20)
```

If you want to sample with replacement,

```
> sample(state.name, 20, replace=TRUE)
```

Suppose you wish to create two vectors, one containing a random sample of 20 of the states, the other vector containing the remaining 30 states.

We obtain a random sample of size 20 from 1, 2, . . . , 50 and store in the vector `index`:

```
> index <- sample(50, 20)
```

See what this sample looks like:

```
> index
```

`tempA` will contain the random sample of 20 states:

```
> tempA <- state.name[index]
```

`tempB` will contain the remaining 30 states. Recall that in subsetting, the negative of a number means to exclude that observation.

```
> tempB <- state.name[-index]

> tempA

> tempB
```

Data Frames in R

Most data will be stored in data frames, rectangular arrays which usually are formed by combining columns of vectors. `FlightDelays` is an example of a data frame.

```
> data.class(FlightDelays)
```

Subsetting data frames

For subsetting a data frame, use the syntax
`data[row.index, column.index]`.

For instance, row 5, column 3:

```
> FlightDelays[5, 3]
```

or rows 1 through 10, columns 1 and 3:

```
> FlightDelays[1:10, c(1, 3)]
```

or all rows *except* 1 through 10, and keep columns 1 and 3:

```
> FlightDelays[-(1:10), c(1, 3)]
```

To extract *all* rows, but columns 1 and 3

```
> FlightDelays[, c(1, 3)]
```

and rows 1:100 and *all* columns

```
> FlightDelays[1:100, ]
```

Use the `subset` command to extract rows based on some logical condition.

Create a subset of just the Tuesday data:

```
> DelaysTue <- subset(FlightDelays, subset = Day == "Tue")
> head(DelaysTue)
```

Create a subset of just the Tuesday data and columns $1, 6, 7$:

```
> DelaysTue <- subset(FlightDelays, Day == "Tue", select = c(1, 6, 7))
> head(DelaysTue)
```