Introduction to R

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Some materials are borrowed from the EXST 7142/7152 data mining courses by Dr. Bin Li at Statistics Dept.
Outline

• R basics
  – What is R
  – How to run R codes
  – Basic syntax
  – R as a calculator
  – Data classes and objects in R
  – Flow control structures
  – Functions
  – How to install and load R packages
What is R

• R is an integrated suite of software facilities for
  – importing, storing, exporting and manipulating data;
  – scientific computation;
  – conducting statistical analyses;
  – displaying the results by tables, graphs, etc.
• Highly customizable via thousands of freely available packages.
• R is also a platform for the development and implementation of new algorithms.
• Many graphical user interface to R both free and commercial
  (e.g. Rstudio and Revolution R (now Microsoft R) ).
What is R

- R mailing lists: [http://www.R-project.org/mail.html](http://www.R-project.org/mail.html)
  - R-announce: announcements of major R developments.
  - R-packages: announcements of new R packages.
  - R-help: main discussion list.
  - R-devel: discussion on code development in R.
  - Special interest group (e.g. R-SIG-Finance).
History of R

• R is a dialect of the S language
  – S was created in 1976 at the Bell Labs as an internal statistical analysis environment
  – Goal of S was “to turn ideas into software, quickly and faithfully".
  – Most well known implementation is S-plus (most recent stable release was in 2010). S-Plus integrates S with a nice GUI interface and full customer support.

• R was created by Ross Ihaka and Robert Gentleman at the University of Auckland, New Zealand.

• The R core group was formed in 1997, who controls the source code of R (written in C)

• The first stable version R 1.0.0 was released in 2000

• Latest stable version is 4.0.3 released on Oct 10, 2020
Features of R

• R is a language designed for statistical analysis
• Available on most platform/OS
• Rich data analysis functionalities and sophisticated graphical capabilities
• Active development and very active community
  – CRAN: The Comprehensive R Archive Network
    • Source code and binaries, user contributed packages and documentation
  – More than 16,000 packages available on CRAN (as of October 2020)
    • 6,000 five years ago
• Free to use!
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Installing and Loading R

• On your PC
  – R console can be downloaded from: http://cran.r-project.org/
  – Rstudio is the de facto environment for R on a desktop system

• On a cluster
  – R is installed on all LONI and LSU HPC clusters
    • QB2: r/3.5.3/INTEL-18.0.1
    • QB3: r/3.6.2/intel-19.0.5
    • SuperMIC: r/3.5.3/INTEL-18.0.1
    • SuperMike2: r/3.5.3/INTEL-18.0.0
  – User requested R
    • Usually installed in user home directory
R Console

• Linux/Mac/Windows version available
• Limited graphic user interface (GUI)
• Command line interface (CLI) is similar to HPC environment
R Console

R version 3.2.5 (2016-04-14) -- "Very, Very Secure Dishes"
Copyright (C) 2016 The R Foundation for Statistical Computing
Platform: x86_64-w64-mingw32/x64 (64-bit)

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.

>
RStudio

• Similar graphic user interface (GUI) to other Windows software, dividing the screen into panes
  – Source code
  – Console
  – Workspace
  – Others (help message, plot etc.)

• Rstudio in a desktop environment is better suited for development and/or a limited number of small jobs
On LONI and LSU HPC Clusters

• Two modes to run R on clusters
  – Interactive mode
    • Type `R` command to launch the console
    • Run R commands in the console
  – Batch mode
    • Write the R script first, then submit a batch job to run it (use the `Rscript` command)
    • This mode is better for production runs
On LONI and LSU HPC Clusters

R version 3.4.3 (2017-11-30) -- "Kite-Eating Tree"
Copyright (C) 2017 The R Foundation for Statistical Computing
Platform: x86_64-pc-linux-gnu (64-bit)

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'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.
Clusters are Better for Resource-demanding Jobs

Training random forest model
Resampling method: 10-fold cross-validation
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Basic Syntax

• The default R prompt is the greater-than sign (>)
  > 2*4
  [1] 8
  > options(prompt="R>")
  R>
• If a line is not syntactically complete, a continuation prompt (+) appears.
  > 2*
  + 4
  [1] 8
• Assignment operators are the left arrow (←) and =. They both assign the value of the object on the right to the object on the left.
  > x <- 2*4
• The contents of the object x can be viewed by typing value at the R prompt
  > x
  [1] 8
Basic Syntax

• Last expression can be retrieved through an internal object `.Last.value`
  
  ```r
  > 2*4
  [1] 8
  > x <- .Last.value
  > x
  [1] 8
  ```

• Removing objects with the function `rm()`
  
  ```r
  > rm(x)
  > x
  Error: object 'value' not found
  ```

• Legal R Names
  
  – names for R objects can be any combination of letters, numbers and periods (`.`) but must not start with a number nor period

• **Note**: **R is case sensitive. X and x are different in R.**
  
  ```r
  > x <- 8
  > X
  Error: object 'X' not found
  ```
Basic Syntax

- Function to clear the console in R and Rstudio
  ```r
  > cat("\014")
  ```
  The code above is the same as `CTRL + L`
- The saved object or function will not be affected
  ```r
  > x
  [1] 8
  ```
- In R, any line starting with “#” will be interpreted as a comment
  ```r
  > # z <- 2*4
  > # Nothing will happen
  ```
Basic Syntax

• R allows automatic completion of type function or object name via the TAB key
  — Convenient, also error-proof
  — If there is no unique name, all matching names will show

• R allows using the up arrow key “↑” -- the previous command you entered shows up on the command line
Basic Syntax

- Avoid assignment to built in functions
  - R has a number of built in functions e.g. `c`, `T`, `F`, `t`
  - An easy way to avoid this problem is to check the contents of the object you wish to use, this also stops you from overwriting the contents of a previously saved object

```
> X    # object with no value assigned
Error: object 'value' not found
> x    # object with a value assigned
[1] 8
> T    # Built in R value
[1] TRUE
> t    # Built in R function
function (x)
UseMethod("t")
```

- Spaces
  - R will ignore extra spaces between object names and operators
    ```
    > x <- 2 * 4
    [1] 8
    ```
  - Spaces cannot be placed between the `<` and `-` in the assignment operator
    ```
    > x <- -2 * 4
    [1] FALSE
    ```
R as a Calculator

• Arithmetic operators and parentheses
  > (1+2)/(3*2)
  > [1] 0.5

• Power operator
  > 2^3
  [1] 8
  > 4^0.5
  [1] 2
  > sqrt(4)
  [1] 2

• Scientific notation
  > 2.1e2
  [1] 210
R as a Calculator

- Exponential function
  > exp(1); exp(0) # ; is the newline separate commands
  [1] 2.718282
  [1] 1
- Inf means "non-finite numeric value"
  > x <- 1/0
  > x
  [1] Inf
  > y <- -1/0
  > y
  [1] -Inf
- NaN means "not a number"
  > x+y
  [1] NaN
- pi
  > pi
  [1] 3.141593
  > help(pi) # Get help from R. You can also use ?pi
R as a Calculator

• Comparisons: <, <=, >, >=, ==, !=
  
  > 1 > 2
  > 1 != 2

• Logical operations
  – NOT: !
  – AND (element wise): &
  – OR (element wise): |
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Data Classes

• R has five atomic classes
  – **Two numeric classes** (numeric (double) or special type integer)
    • Numbers in R are treated as numeric unless specified otherwise.
      > x <- 605
      > x
      [1] 605
  – **Complex**
    > cn <- 2 + 3i
    > cn
    [1] 2 + 3i
  – **Character**
    > string <- “Hello World”
    > string
    [1] “Hello World”
  – **Logical**
    • TRUE, FALSE or NA. The code missing values in R is NA.
      > 2 < 4
      [1] TRUE
      > value <- NA
      > is.logical(value)
Data Classes

• The function `class()` can determine the class of each object

  ```
  > class(x)
  [1] "numeric"
  > class(string)
  [1] "character"
  > class(cn)
  [1] "complex"
  ```

• The `is.<type>()` functions check the data classes

  ```
  > is.numeric(x)
  [1] TRUE
  > is.character(string)
  ```

• The `as.<type>()` functions convert an object to a different type

  ```
  > as.character(x)
  ```
Data Objects

• R Data objects
  – **Vector**: elements of same class, one dimension
  – **Matrix**: elements of same class, two dimensions
  – **Array**: elements of same class, 2+ dimensions
  – **Lists**: elements can be any objects
  – **Data frames**: “datasets” where columns are variables and rows are observations
Data Objects - Vectors

- Vectors can only contain elements of the same data class
- Vectors can be constructed by
  - Using the `c()` function (concatenate)
    ```r
    > d <- c(1,2,3)  ##numeric
    > d <- c("1","2","3") ##character
    > value.logical <- c(F,F,T)  ##logical
    ```
  - you can convert an object with `as.TYPE()` functions
    ```r
    > as.numeric(d)
    ```
  - Coercion will occur when mixed objects are passed to the `c()` function, as if the `as.<Type>()` function is explicitly called
    ```r
    > y <- c(1.7, "a") ## character
    > y <- c(TRUE, 2) ## numeric
    > y <- c("a", TRUE) ## character
    ```
Data Objects - Vectors

• Vectors can also be constructed by
  – Using the `vector()` function
    > x <- vector("numeric", length = 10)
    > x
    [1] 0 0 0 0 0 0 0 0 0 0
  – Using `seq()` or `rep()` function
    > x <- seq(from=2, to=10, by=2)
    > x <- seq(from=2, to=10, length=5)
    > x <- rep(5, 6)
  – Using “:” operator
    > x <- 0:6

• Vectors can be created using a combination of these functions.
  > value1 <- c(1, 2:4, rep(3, 4), seq(from=1, to=6, by=2))
  > value2 <- rep(c(1, 2), 3)
  > value3 <- rep(c(1, 2), each=3)
Data Objects - Vectors

• NA in R means missing value
  > weight <- c(60, 72, NA, 90, 95, 72)  # unit is kg, contents after the # sign are comments
  > weight
  [1] 60 72 NA 90 95 72
  > height <- c(1.75,1.80,1.65,1.90,1.74,1.91)  # unit: meter

• Vector based operations are very fast!
  > bmi <- weight/height^2  # bmi stands for body mass index
  > bmi
  > mean(weight)
  [1] NA
  > mean(weight, na.rm=TRUE)
  [1] 77.8
  > sd(weight, na.rm=T)
  [1] 14.39444
  > median(weight, na.rm=T)
  [1] 72
  > round(height, d=1)
  [1] 1.8 1.8 1.6 1.9 1.7 1.9
Vectors Indexing

- One can use \[<\text{index}>\] to access individual element of interest
  - Indices start from 1

```r
> x <- 1:10
> x[4] ## individual element of a vector
> x[1,4] ## how about multiple elements?
Error in x[1,4] : incorrect number of dimensions
> x[c(1,4)] ## this is the correct way
[1] 1 4
> x[c(1,8:9,3)] ## not necessarily in order
[1] 1 8 9 3
> x[-1] ## negative indices drop elements
[1] 2 3 4 5 6 7 8 9 10
> x[-1:-5]
[1] 6 7 8 9 10
> x[c(T,T,T,T,F,F,F,F,F)] ## Can use logical values as indices
[1] 1 2 3 4 5
> x[c(T,F)] ## Use a pattern
[1] 1 3 5 7 9
```
Exercises 1

1. Create a vector of the positive odd integers less than 100, save it to “x” (Hint: use seq function).
2. Only access the values less than 18 in x.
Exercises 1 - solution

1. \( x \leftarrow \text{seq(from=1, to=100, by=2)} \)
2. \( x[c(1:9)] \)
Data Objects - Matrices

- Matrices are vectors with a dimension attribute
- R matrices can be constructed by
  - Using the `matrix()` function
    ```r
    > m <- matrix(1:12, nrow=3, ncol=4)
    > m
    [1,]  1  4  7 10
    [2,]  2  5  8 11
    [3,]  3  6  9 12
    ```
  - R matrices are constructed column-wise by default
    ```r
    > m <- matrix(1:12, nrow=3, ncol=4, byrow=F)  ## is the same as x <- matrix(1:12, nrow=3, ncol=4)
    > m <- matrix(1:12, nrow=3, ncol=4, byrow=T)  ## try this one
    ```
Data Objects - Matrices

- R matrices can also be constructed by
  - Passing an `dim` attribute to a vector
    ```r
    > m <- 1:10
    > m
    [1] 1 2 3 4 5 6 7 8 9 10
    > dim(m) <- c(2, 5)
    > m
    [1,]   1   3   5   7   9
    [2,]   2   4   6   8  10
    ```
  - Using `cbind()` or `rbind()` functions
    ```r
    > x <- 1:3
    > y <- 10:12
    > cbind(x, y)
    x  y
    [1,] 1 10
    [2,] 2 11
    [3,] 3 12
    > rbind(x, y)
    [,1] [,2] [,3]
    x 1 2 3
    y 10 11 12
    ```
Data Objects – Arrays

• Elements of same class with a number of dimensions
  – Vectors and matrices are arrays of 1 and 2 dimensions
  – Function `array()` creates an array with given dimensions

```r
> # An array with 8 elements and 3 dimensions
> m <- array(data = 1:8, dim = c(2,2,2))
> m
,
[,1] [,2]
[1,]   1   3
[2,]   2   4
,
[,3] [,2]
[1,]  5   7
[2,]  6   8
```
Data Objects - Lists

• Lists are an ordered collection of objects (which can be of different types or classes and different lengths)
• Lists can be constructed by using the `list()` function

```r
> x <- c(31, 32, 40)
> y <- factor(c("F", "M", "M", "F"))
> z <- c("London", "New York")
> my_list <- list(x,y,z)
> my_list
[[1]]
[1] 31 32 40

[[2]]
[1] F M M F
Levels: F M

[[3]]
[1] "London" "New York"
```
Data Objects - Lists

- Elements of R objects can have names, `names()` function can display:
  ```r
  > names(my_list)
  NULL
  ```
- Names can be assigned
  ```r
  > names(my_list) <- c("age","sex","city")
  > names(my_list)
  [1] "age" "sex" "city"
  ```
- Or can be assigned when creating a list.
  ```r
  > my_list2 <- list(age=x,sex=y,city=z)
  > names(my_list2)
  [1] "age" "sex" "city"
  ```
Lists Indexing

• Using two equivalent ways to access the first component (e.g. age in my_list):
  – the \[ \] operator
    > my_list[[1]]
    [1] 31 32 40
  – the "$" sign if the elements of list have names
    > my_list$age
    [1] 31 32 40

• Referring individual element
  > my_list$age[1]
  [1] 31
Data Objects - Data Frames

- Data frames are used to store tabular data
  - They are a special type of lists where every element (i.e. “column” or “variable”) has to be of the same length, but can be of different class
  - Why do we need data frames if it is simply a list? - More efficient storage, and indexing!
  - Data frames can have special attributes such as row.names
  - Data frames can be created by
    - combining elements with the same length using data.frame() functions
    - reading data files, using functions such as read.table() or read.csv()
Data Objects - Data Frames

• Data frames can be created directly by calling `data.frame()`

```r
> my_df <- data.frame(age=c(31,40,50), sex=c("M","F","M"))
> my_df
          age sex
1        31   M
2        40   F
3        50   M
```

• Column names can be assigned

```r
> names(my_df) <- c("c1","c2")
> my_df
     c1 c2
1  31  M
2  40  F
3  50  M
```
Data Objects - Data Frames

- Row names are automatically assigned and are by default labelled “1”, “2”, “3”, ...
  ```r
  > row.names(my_df)
  [1] "1" "2" "3"
  ```
- These can also be renamed if desired
  ```r
  > row.names(my_df)<-c("r1","r2","r3")
  > my_df
  c1  c2
  r1 31  M
  r2 40  F
  r3 50  M
  ```
Matrices and Data Frames Indexing

• One can use \([<\text{index}>,<\text{index}>]\) to access individual element
  > my_df[1,2]
  [1] M

• Indexing by columns
  > my_df[,1]
  [1] 31 40 50
  > my_df[,1:2]
  age  sex
  1 31  M
  2 40  F
  3 50  M

• Indexing by rows
  > my_df[1,]
  age  sex
  1 31  M
  > my_df[2:3,]
  age  sex
  2 40  F
  3 50  M
Matrices and Data Frames Indexing

• the "\$" sign if the elements of matrix/dataframe have names
  > my_df$sex
  [1] M F M
  Levels: F M
  > my_df$sex[2] ## Referring individual element

  [1] F
  Levels: F M

• the [ [] ] operator
  > my_df[[1]]
  [1] 31 40 50
  > my_df[[1]][1]
  [1] 31
  > my_df[[3]][1]
  Error in .subset2(x, i, exact = exact) : subscript out of bounds
Matrices and Data Frames Indexing

- Indexing can be conditional on the variable itself or on another variable!

```r
> pain <- c(0, 3, 2, 2, 1)
> sex <- factor(c("M", "M", "F", "F", "M"))
> age <- c(45, 51, 45, 32, 90)
> which(sex=="M")
[1] 1 2 5
> pain[sex=="M"]
[1] 0 3 1
> pain[age>32]
[1] 0 3 2 1
> pain[(age>32)&(sex=="M")]
[1] 0 3 1
> pain[(age>=49)|(age<41)]
[1] 3 2 1
> my_df
   age sex
1  31 M
2  40 F
3  50 M
> my_df$age[my_df$sex=="M"]
[1] 31 50
```
Querying Object Attributes

• The `length()` function
• The `class()` function
• The `dim()` function
• The `str()` function
• The `attributes()` function reveals attributes of an object
  – Class
  – Names
  – Dimensions
  – Length
  – User defined attributes
• They work on all objects (including functions)
• More examples in the “Data inspection” section
Exercises 2

1. In the Exercises 1, a vector `x <- seq(from=1,to=100,by=2)` has been created. What if we want to exclude the values greater than 40 and less than 80?

2. Create a data frame called “cone” with three elements. The first two elements are radiiuses and heights of the cones:

   \[
   \frac{1}{3} \pi R^2 H.
   \]

   Make the third element as `V`, which is the volume of the cone.
Exercises 2 - solution

1. \( x[x>40 \ & \ x<80] \)

2. 
   \[
   \begin{align*}
   &\text{R} \leftarrow \text{c}(2.27, 1.98, 1.69, 1.88, 1.64, 2.14) \\
   &\text{H} \leftarrow \text{c}(8.28, 8.04, 9.06, 8.70, 7.58, 8.34) \\
   &\text{V} \leftarrow \frac{1}{3}\pi R^2 H \\
   &\text{data.frame(R,H,V)}
   \end{align*}
   \]
   
   \[1\] 44.67974 33.00768 27.09756 32.20057 21.34939 39.99652
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Flow Control Structures

- Control structures allow one to control the flow of execution.
  - Similar to other script languages

<table>
<thead>
<tr>
<th>Keyword</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>if ... else</td>
<td>testing a condition</td>
</tr>
<tr>
<td>for</td>
<td>executing a loop (with fixed number of iterations)</td>
</tr>
<tr>
<td>while</td>
<td>executing a loop when a condition is true</td>
</tr>
<tr>
<td>repeat</td>
<td>executing an infinite loop</td>
</tr>
<tr>
<td>break</td>
<td>breaking the execution of a loop</td>
</tr>
<tr>
<td>next</td>
<td>skipping to next iteration</td>
</tr>
<tr>
<td>return</td>
<td>exit a function</td>
</tr>
</tbody>
</table>
Testing Conditions

# Comparisons: <, <=, >, >=, ==, !=

# Logical operations:
# !: NOT
# &: AND (element wise)
# &&: AND (only leftmost element)
# |: OR (element wise)
# ||: OR (only leftmost element)

An example if.R

```r
> x <- 10
> if(x > 3 && x < 5) {
+   print("x is between 3 and 5")
+ } else if(x <= 3) {
+   print("x is less or equal to 3")
+ } else {
+   print("x is greater or equal to 5")
+ }
[1] "x is greater or equal to 5"
```
For Loops

# Syntax
# for (value in sequence) {
#   statements
# }

An example for R

```r
> x <- c(2,5,3,9,8,11,6)
> count <- 0
> for (i in x) {
+   if (i %% 2 == 0) count <- count+1
+ }
> count
[1] 3
```

# Loops are not very frequent used because of many inherently vectorized operations and the family of `apply()` functions (more on this later)
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## Simple Statistical Functions

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>min()</td>
<td>Minimum value</td>
</tr>
<tr>
<td>max()</td>
<td>Maximum value</td>
</tr>
<tr>
<td>which.min()</td>
<td>Location of minimum value</td>
</tr>
<tr>
<td>which.max()</td>
<td>Location of maximum value</td>
</tr>
<tr>
<td>sum()</td>
<td>Sum of the elements of a vector</td>
</tr>
<tr>
<td>mean()</td>
<td>Mean of the elements of a vector</td>
</tr>
<tr>
<td>sd()</td>
<td>Standard deviation of the elements of a vector</td>
</tr>
<tr>
<td>quantile()</td>
<td>Show quantiles of a vector</td>
</tr>
<tr>
<td>summary()</td>
<td>Display descriptive statistics</td>
</tr>
</tbody>
</table>

```r
> mean(weight, na.rm=T)
[1] 77.8
> which.min(weight)
[1] 1
> min(weight, na.rm=T)
[1] 60
>```
Distributions and Random Variables

• For each distribution R provides four functions: density (d), cumulative density (p), quantile (q), and random generation (r)
  – The function name is of the form \([d|p|q|r]<\text{name of distribution}>\)
  – e.g. \(q\text{binom}()\) gives the quantile of a binomial distribution

<table>
<thead>
<tr>
<th>Distribution</th>
<th>Distribution name in R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uniform</td>
<td>unif</td>
</tr>
<tr>
<td>Binomial</td>
<td>binom</td>
</tr>
<tr>
<td>Poisson</td>
<td>pois</td>
</tr>
<tr>
<td>Geometric</td>
<td>geom</td>
</tr>
<tr>
<td>Gamma</td>
<td>gamma</td>
</tr>
<tr>
<td>Normal</td>
<td>norm</td>
</tr>
<tr>
<td>Log Normal</td>
<td>lnorm</td>
</tr>
<tr>
<td>Exponential</td>
<td>exp</td>
</tr>
<tr>
<td>Student’s t</td>
<td>t</td>
</tr>
</tbody>
</table>
Distributions and Random Variables

• Generating random number from normal distribution
  > set.seed(1)
  > rnorm(2,mean=0,sd=1)
  [1] -0.6264538  0.1836433

  > pnorm(1.96)
  [1] 0.9750021

• The inverse of the above function call
  > qnorm(0.975)
  [1] 1.959964
Sorting and Random Samples

- **Sort and order elements:** `sort()`, `rank()` and `order()`.

```r
> x <- c(1.2, 0.4, 2.3, 0.9)
> sort(x)  ## sort x in ascending order
> sort(x, decreasing = T)  ## sort x in descending order
> rank(x)
[1] 3 1 4 2
> order(x)  ## order() returns the indices of the vector in sorted order
[1] 2 4 1 3
```
Sorting and Random Samples

- Random sampling function `sample()`. 
  ```
  > sample(1:4,4,replace=F)
  > sample(1:10,10,replace=F)
  > sample(1:10,10,replace=T)  ## will be different from the last run
  > sample(1:4,10,replace=T,prob=c(.2,.5,.2,.1))
  ```

- Using the same seed value through `set.seed()` can reproduce the same outcome.
  ```
  > set.seed(1)
  > sample(1:4,10,replace=T)
  [1] 2 2 3 4 1 4 4 3 3 1
  > set.seed(1)
  > sample(1:4,10,replace=T)
  [1] 2 2 3 4 1 4 4 3 3 1
  ```
The **table** Function

- **The table() function** is useful to tabulate factors or find the frequency of an object.
- **Example:** The quine dataset consists of 146 rows describing children's ethnicity (Eth), age (Age), sex (Sex), days absent from school (Days) and their learning ability (Lrn).
  - If we want to find out the frequency of the age classes in quine dataset
    
    ```
    > library(MASS)
    > table(quine$Age)
    F0 F1 F2 F3
    27 46 40 33
    ```
  - If we need to know the breakdown of ages according to sex
    
    ```
    > table(quine$Sex,quine$Age)
    
    F0 F1 F2 F3  
    F 10 32 19 19  
    M 17 14 21 14
    ```
The apply Function

- The `apply()` function evaluate a function over the margins of an array
  - More concise than the `for` loops (not necessarily faster)

# X: array objects
# MARGIN: a vector giving the subscripts which the function will be applied over
# FUN: a function to be applied

```r
> str(apply)
function (X, 2, FUN, ...)
```
```r
> x <- matrix(rnorm(200), 20, 10)
> apply(x, 1, mean)
25% -0.52753974 -0.1084101 -1.1327258 -0.9473914 -1.176299 -0.4790660
75%  0.05962769  0.6818734  0.7354684  0.5547772  1.066931  0.6359116
25% -0.1968380 -0.5063218 -0.8846155 -1.54558614 -0.8847892 -0.2001400
75%  0.7910642  0.3893138  0.8881821 -0.06074355  0.5042554  0.9384258
25% -0.5378145 -1.08873676 -0.5566373 -0.3189407 -0.6280269 -0.6979439
75%  0.6438305 -0.02031298  0.3495564  0.3391990 -0.1151416  0.2936645
     [,19]       [,20]
25% -0.259203 -0.1798460
75%  1.081322  0.8306676
```

Other apply Functions

- **lapply** - Loop over a list (data frame) and evaluate a function on each element
- **sapply** - Same as lapply but try to simplify the result

```r
## lapply & sapply example
> x <- list(a = 1, b = 1:3, c = 10:100)
> lapply(x, FUN = length)
> sapply(x, FUN = length)
> lapply(x, FUN = sum)
> sapply(x, FUN = sum)
```
Other apply Functions

- In statistics, one of the most basic activities is computing statistic of variables
- `tapply` - Apply a function over subsets of a vector
- `mapply` - Multivariate version of `lapply`

```r
## generate medical data for tapply example (https://www.r-bloggers.com/r-function-of-the-day-tapply-2/)
> medical.example <-
+   data.frame(patient = 1:100,
+              age = rnorm(100, mean = 60, sd = 12),
+              treatment = gl(2, 50,
+                            labels = c("Treatment", "Control")))
> tapply(medical.example$age, medical.example$treatment, mean)
Treatment  Control
  61.7065   59.9123
```
User Defined Functions

• Similar to other languages, functions in R are defined by using the `function()` directives
• The return value is the last expression in the function body to be evaluated
• Functions can be nested
• Functions are R objects
  – For example, they can be passed as an argument to other functions
Example of User Defined Function

```
# Syntax
# function_name <- function (arguments) {
#   statement
# }
#
# Define the function for the power calculation
> pow <- function(x, y) {
+   result <- x^y
+}
#
# Call the function
> c <- pow(4,2)
> c
[1] 16
```
Outline

• R basics
  – What is R
  – How to run R codes
  – Basic syntax
  – R as a calculator
  – Data classes and objects in R
  – Flow control structures
  – Functions
  – How to install and load R packages
Installing and Loading R Packages - PC

• Installation:
  – Option 1: menu item
  – Option 2: run `install.packages("<package name>")` function in the console

• Loading: the `library(<package name>)` function load previously installed packages

• Libraries that R currently searching can be shown with `.libPaths()`
Installing and Loading R Packages - Cluster

• Installation
  – You most likely do NOT have root privilege
  – Point the environment variable `R_LIBS_USER` to a desired location
  – Use the `install.packages("<package name>")` function to install a library

• Loading: the `library(<package name>)` function load previously installed packages

• Libraries that R currently searching can be shown with `.libPaths()`
[ychen64@mike002 ~]$ export R_LIBS_USER=/home/ychen64/packages/R/libraries
[ychen64@mike002 ~]$ echo $R_LIBS_USER
/home/ychen64/packages/R/libraries
[ychen64@mike002 ~]$ R

R version 3.3.3 (2017-03-06) -- "Another Canoe"
Copyright (C) 2017 The R Foundation for Statistical Computing
Platform: x86_64-pc-linux-gnu (64-bit)
...

> .libPaths()
[1] "/home/ychen64/packages/R/libraries"
[2] "/home/packages/r/3.4.3/INTEL-18.0.0/lib64/R/library"

> install.packages("swirl")
> library(swirl)

| Hi! Type swirl() when you are ready to begin.
Listing and Unloading
R Packages - PC and Cluster

- List all available packages `library()`, press “q” to quit
- List all packages in the default library (on the SuperMike2 cluster the default is `/home/packages/r/3.5.3/INTEL-18.0.0/lib64/R/library`): `library(lib = .Library)`
- Show currently loaded libraries: the `search()` function or `sessionInfo()` function
- Check package version: `packageVersion("<package name>")`
- Unload `detach(package:<package name>)`
$ R

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Platform: x86_64-pc-linux-gnu (64-bit)

> library()
> library(lib = .Library)

> search()
[1] "\.GlobalEnv" "package:swirl" "package:stats"
[10] "package:base"
> packageVersion("swirl")
> detach(package:swirl)
Updating and Uninstall R Packages - PC and Cluster

- **Update** `update.packages("<package name>")`
- **Uninstall** `remove.packages("<package name>")`
- Documentation page: http://www.hpc.lsu.edu/docs/faq/installation-details.php
[ychen64@mike002 ~]$ R

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Platform: x86_64-pc-linux-gnu (64-bit)

...>

> update.packages("swirl")
> remove.packages("swirl")
Steps for Data Analysis

• Get the data
• Read and inspect the data
• Preprocess the data (remove missing and dubious values, discard columns not needed etc.)
• Analyze the data
• Generate the report
Take-home message

• R basics
  — What is R
  — How to run R codes on PC and cluster
  — Basic syntax (variable assignment)
  — R as a calculator
  — Data classes and objects in R (dataframe!)
  — Flow control structures
  — Functions (basic statistical functions)
  — How to install and load R packages
Not Covered

• Data acquisition
• Data inspection
• Report generation
• Data manipulation
• Statistical analysis (e.g. regression models, machine learning/data mining)
• Advanced graphics in R
• Parallel processing in R
Learning R

• User documentation on CRAN
  – An Introduction on R: http://cran.r-project.org/doc/manuals/r-release/R-intro.html

• Online tutorials (tons of them)
  – http://www.cyclismo.org/tutorial/R/

• Online courses (e.g. Coursera)

• Blogs
  – https://www.r-bloggers.com

• Educational R packages
  – Swirl: Learn R in R
Next HPC Training

• Introduction to Python, October 28.
• Weekly trainings during regular semester
  – Wednesdays “9:00am-11:00am” session, pure Zoom
• Programming/Parallel Programming workshops
  – Usually in summer
More R Tutorials – Data Analysis in R

• You will learn the data analysis fundamentals with applications in R.
• The data pre-processing using R will be introduced first, then some basic statistical analysis methods such as linear regression, classification as well as re-sampling methods for the basic machine learning will be covered.
More R Tutorials – Data Visualization in R

• This training provided an introduction to the R graphics in detail
• An overview on how to create and save graphs in R, then focus on the ggplot2 package.
• http://www.hpc.lsu.edu/training/archive/tutorials.php
More R Tutorials – Parallel Computing with R

• This training focused on how to use the "parallel" package in R and a few related packages to parallelize and enhance the performance of R programs

• http://www.hpc.lsu.edu/training/archive/tutorials.php
Getting Help

• User Guides
  – LSU HPC: http://www.hpc.lsu.edu/docs/guides.php#hpc
  – LONI:http://www.hpc.lsu.edu/docs/guides.php#loni
• Documentation: http://www.hpc.lsu.edu/docs
• Contact us
  – Email ticket system: sys-help@loni.org
  – Telephone Help Desk: 225-578-0900
Questions?