Basics of R Programming

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R and Data Mining Course
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Quiz

RDM

- Have you used R before?

Quiz

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- Are you familiar with data mining and machine learning techniques and algorithms?

Quiz

- Have you used R before?
- Are you familiar with data mining and machine learning techniques and algorithms?
- Have you used R for data mining and analytics in your work?

Outline

What is R?

- R [1] is a free software environment for statistical computing and graphics.
- R can be easily extended with 13,000+ packages available on CRAN[2] (as of Dec 2018).
- Many other packages provided on Bioconductor[3], R-Forge[4], GitHub[5], etc.
- R manuals on CRAN[6]
  - *An Introduction to R*
  - *The R Language Definition*
  - *R Data Import/Export*
  - ...

[1] `http://www.r-project.org/`
[2] `http://cran.r-project.org/`
[3] `http://www.bioconductor.org/`
[4] `http://r-forge.r-project.org/`
[5] `https://github.com/`
[6] `http://cran.r-project.org/manuals.html`

Why R?

- R is widely used in both academia and industry.
- R is one of the most popular tools for data science and analytics, ranked #1 from 2011 to 2016, but sadly overtaken by Python since 2017, :-([7].
- *The CRAN Task Views* [8] provide collections of packages for different tasks.
  - Machine learning & atatistical learning
  - Cluster analysis & finite mixture models
  - Time series analysis
  - Multivariate statistics
  - Analysis of spatial data
  - ...

[7] The KDnuggets polls on *Top Analytics, Data Science software* https://www.kdnuggets.com/2018/05/poll-tools-analytics-data-science-machine-learning-results.html

[8] http://cran.r-project.org/web/views/

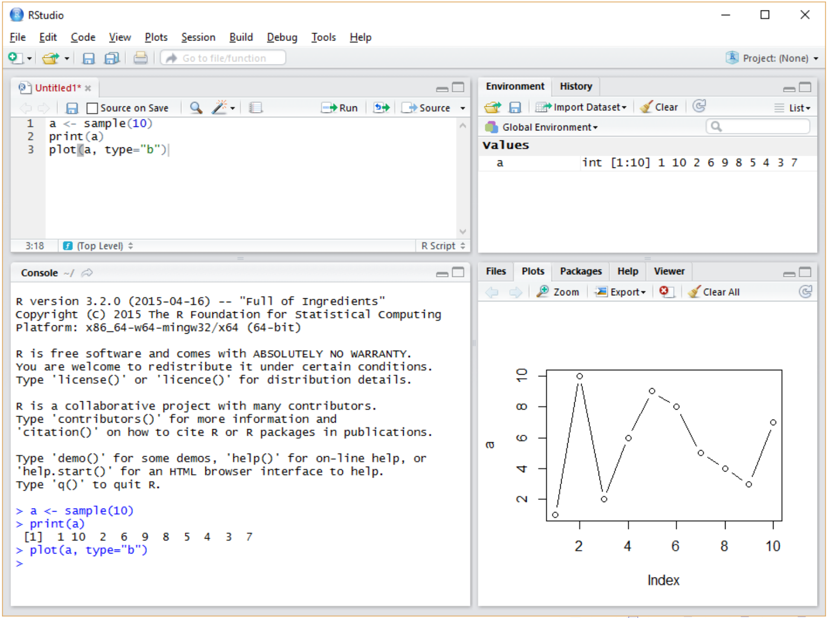
Outline

RStudio[9]

- An integrated development environment (IDE) for R
- Runs on various operating systems like Windows, Mac OS X and Linux
- Suggestion: always using an RStudio project, with subfolders
  - code: source code
  - data: raw data, cleaned data
  - figures: charts and graphs
  - docs: documents and reports
  - models: analytics models

[9] https://www.rstudio.com/products/rstudio/

RStudio


RStudio
File Edit Code View Plots Session Build Debug Tools Help
Go to file/function
Project: (None)
Untitled1*
Source on Save
Run
Source
1 a <- sample(10)
2 print(a)
3 plot(a, type="b")
3:18
(Top Level)
R Script
Environment History
Import Dataset
Clear
List
Global Environment
Values
a int [1:10] 1 10 2 6 9 8 5 4 3 7
Console ~/
R version 3.2.0 (2015-04-16) -- "Full of Ingredients"
Copyright (C) 2015 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.
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.
> a <- sample(10)
> print(a)
[1] 1 10 2 6 9 8 5 4 3 7
> plot(a, type="b")
>
Files Plots Packages Help Viewer
Zoom
Export
Clear All
a
2
4
6
8
10
Index

RStudio Keyboard Shortcuts

- Run current line or selection: Ctrl + enter
- Comment / uncomment selection: Ctrl + Shift + C
- Clear console: Ctrl + L
- Reindent selection: Ctrl + I

Writing Reports and Papers

- Sweave + LaTex: for academic publications
- beamer + LaTex: for presentations
- knitr + R Markdown: generating reports in HTML, PDF and WORD formats
- Notebook: R notebook, Jupiter notebook

Outline

Pipe Operations

- Load library magrittr for pipe operations
- Avoid nested function calls
- Make code easy to understand
- Supported by `dplyr` and `ggplot2`

```
library(magrittr) ## for pipe operations
## traditional way
b <- fun3(fun2(fun1(a), b), d)
## the above can be rewritten to
b <- a %>% fun1() %>% fun2(b) %>% fun3(d)
```

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```

Quiz: Why not use 'c' in above example?

Outline

Data Types and Structures

- Data types
  - Integer
  - Numeric
  - Character
  - Factor
  - Logical
- Data structures
  - Vector
  - Matrix
  - Data frame
  - List

Vector

```
## integer vector
x <- 1:10
print(x)
##  [1]  1  2  3  4  5  6  7  8  9 10

## numeric vector, generated randomly from a uniform distribution
y <- runif(5)
y
## [1] 0.85400580 0.66021467 0.08613575 0.43215580 0.95526792

## character vector
(z <- c("abc", "d", "ef", "g"))
## [1] "abc" "d"   "ef"  "g"
```

Matrix

```
## create a matrix with 4 rows, from a vector of 1:20
m <- matrix(1:20, nrow=4, byrow=T)
m
##      [,1] [,2] [,3] [,4] [,5]
## [1,]    1    2    3    4    5
## [2,]    6    7    8    9   10
## [3,]   11   12   13   14   15
## [4,]   16   17   18   19   20

## matrix subtraction
m - diag(nrow=4, ncol=5)
##      [,1] [,2] [,3] [,4] [,5]
## [1,]    0    2    3    4    5
## [2,]    6    6    8    9   10
## [3,]   11   12   12   14   15
## [4,]   16   17   18   18   20
```

Data Frame

```
library(magrittr)
age <- c(45, 22, 61, 14, 37)
gender <- c("Female", "Male", "Male", "Female", "Male")
height <- c(1.68, 1.85, 1.80, 1.66, 1.72)
married <- c(T, F, T, F, F)
df <- data.frame(age, gender, height, married) %>% print()
```

```
##   age gender height married
## 1  45 Female   1.68    TRUE
## 2  22   Male   1.85   FALSE
## 3  61   Male   1.80    TRUE
## 4  14 Female   1.66   FALSE
## 5  37   Male   1.72   FALSE
```

```
str(df)
```

```
## 'data.frame': 5 obs. of  4 variables:
##  $ age    : num  45 22 61 14 37
##  $ gender : Factor w/ 2 levels "Female","Male": 1 2 2 1 2
##  $ height : num  1.68 1.85 1.8 1.66 1.72
##  $ married: logi  TRUE FALSE TRUE FALSE FALSE
```

List

```
x <- 1:10
y <- c("abc", "d", "ef", "g")
ls <- list(x, y) %>% print()
## [[1]]
##  [1]  1  2  3  4  5  6  7  8  9 10
##
## [[2]]
## [1] "abc" "d"   "ef"  "g"

## retrieve an element in a list
ls[[2]]
## [1] "abc" "d"   "ef"  "g"

ls[[2]][1]
## [1] "abc"
```

Outline

Conditional control

- `if ... else ...`

```
score <- 4
if(score>=3) {
  print("pass")
} else {
  print("fail")
}
## [1] "pass"
```

- `ifelse()`

```
score <- 1:5
ifelse(score>=3, "pass", "fail")
## [1] "fail" "fail" "pass" "pass" "pass"
```

Loop control

- `for`, `while`, `repeat`
- `break`, `next`

```
for (i in 1:5) {
  print(i ^ 2)
}
## [1] 1
## [1] 4
## [1] 9
## [1] 16
## [1] 25
```

Apply Functions

- `apply()`: apply a function to margins of an array or matrix
- `lapply()`: apply a function to every item in a list or vector and return a list
- `sapply()`: similar to `lapply`, but return a vector or matrix
- `vapply()`: similar to `sapply`, but as a pre-specified type of return value

Loop vs lapply

```
## for loop
x <- 1:10
y <- rep(NA, 10)
for(i in 1:length(x)) {
  y[i] <- log(x[i])
}
y
##  [1] 0.0000000 0.6931472 1.0986123 1.3862944 1.6094379 1.79...
##  [7] 1.9459101 2.0794415 2.1972246 2.3025851

## apply a function (log) to every element of x
tmp <- lapply(x, log)
y <- do.call("c", tmp) %>% print()
##  [1] 0.0000000 0.6931472 1.0986123 1.3862944 1.6094379 1.79...
##  [7] 1.9459101 2.0794415 2.1972246 2.3025851
```

Outline

Parallel Computing

```
## on Linux or Mac machines
library(parallel)
n.cores <- detectCores() - 1 %>% print()
tmp <- mclapply(x, log, mc.cores=n.cores)
y <- do.call("c", tmp)

## on Windows machines
library(parallel)
## set up cluster
cluster <- makeCluster(n.cores)
## run jobs in parallel
tmp <- parLapply(cluster, x, log)
## stop cluster
stopCluster(cluster)
# collect results
y <- do.call("c", tmp)
```

Parallel Computing (cont.)

On Windows machines, libraries and global variables used by a function to run in parallel have to be explicited exported to all nodes.

```
## on Windows machines
library(parallel)
## set up cluster
cluster <- makeCluster(n.cores)
## load required libraries, if any, on all nodes
tmp <- clusterEvalQ(cluster, library(igraph))
## export required variables, if any, to all nodes
clusterExport(cluster, "myvar")
## run jobs in parallel
tmp <- parLapply(cluster, x, myfunc)
## stop cluster
stopCluster(cluster)
# collect results
y <- do.call("c", tmp)
```

Outline

Functions

Define your own function: calculate the arithmetic average of a numeric vector

```
average <- function(x) {
  y <- sum(x)
  n <- length(x)
  z <- y / n
  return(z)
}

## calcuate the average of 1:10
average(1:10)
## [1] 5.5
```

Outline

Data Import and Export [10]

Read data from and write data to

- R native formats (incl. `Rdata` and `RDS`)
- CSV files
- EXCEL files
- ODBC databases
- SAS databases

R Data Import/Export:

- `http://cran.r-project.org/doc/manuals/R-data.pdf`

[10] Chapter 2: Data Import and Export, in book *R and Data Mining: Examples and Case Studies*. `http://www.rdatamining.com/docs/RDataMining.pdf`

Save and Load R Objects

RDM

- `save()`: save R objects into a `.Rdata` file
- `load()`: read R objects from a `.Rdata` file
- `rm()`: remove objects from R

```
a <- 1:10
save(a, file="./data/dumData.Rdata")
rm(a)
a

## Error in eval(expr, envir, enclos):  object 'a' not found

load("./data/dumData.Rdata")
a
##  [1]  1  2  3  4  5  6  7  8  9 10
```

Save and Load R Objects - More Functions

- `save.image()`:
  save current workspace to a file
  It saves everything!
- `readRDS()`:
  read a single R object from a `.rds` file
- `saveRDS()`:
  save a single R object to a file
- Advantage of `readRDS()` and `saveRDS()`:
  You can restore the data under a different object name.
- Advantage of `load()` and `save()`:
  You can save multiple R objects to one file.

Import from and Export to .CSV Files

- `write.csv()`: write an R object to a .CSV file
- `read.csv()`: read an R object from a .CSV file

```
# create a data frame
var1 <- 1:5
var2 <- (1:5) / 10
var3 <- c("R", "and", "Data Mining", "Examples", "Case Studies")
df1 <- data.frame(var1, var2, var3)
names(df1) <- c("VarInt", "VarReal", "VarChar")
# save to a csv file
write.csv(df1, "./data/dummmyData.csv", row.names = FALSE)
# read from a csv file
df2 <- read.csv("./data/dummmyData.csv")
print(df2)
```

```
##   VarInt VarReal      VarChar
## 1      1     0.1            R
## 2      2     0.2          and
## 3      3     0.3  Data Mining
## 4      4     0.4     Examples
## 5      5     0.5 Case Studies
```

Import from and Export to EXCEL Files

Package *openxlsx*: read, write and edit XLSX files

```
library(openxlsx)
xlsx.file <- "./data/dummmyData.xlsx"
write.xlsx(df2, xlsx.file, sheetName='sheet1', row.names=F)
df3 <- read.xlsx(xlsx.file, sheet='sheet1')
df3
```

```
##   VarInt VarReal      VarChar
## 1      1     0.1            R
## 2      2     0.2          and
## 3      3     0.3  Data Mining
## 4      4     0.4     Examples
## 5      5     0.5 Case Studies
```

Read from Databases

- Package *RODBC*: provides connection to ODBC databases.
- Function `odbcConnect()`: sets up a connection to database
- `sqlQuery()`: sends an SQL query to the database
- `odbcClose()` closes the connection.

```r
library(RODBC)
db <- odbcConnect(dsn = "servername", uid = "userid",
                  pwd = "******")
sql <- "SELECT * FROM lib.table WHERE ..."
# or read query from file
sql <- readChar("myQuery.sql", nchars=99999)
myData <- sqlQuery(db, sql, errors=TRUE)
odbcClose(db)
```

Read from Databases

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- sqlQuery(): sends an SQL query to the database
- odbcClose() closes the connection.

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db <- odbcConnect(dsn = "servername", uid = "userid",
                  pwd = "******")
sql <- "SELECT * FROM lib.table WHERE ..."
# or read query from file
sql <- readChar("myQuery.sql", nchars=99999)
myData <- sqlQuery(db, sql, errors=TRUE)
odbcClose(db)
```

Functions sqlFetch(), sqlSave() and sqlUpdate(): read, write or update a table in an ODBC database

Import Data from SAS

Package *foreign* provides function `read.ssd()` for importing SAS datasets (`.sas7bdat` files) into R.

```
library(foreign) # for importing SAS data
# the path of SAS on your computer
sashome <- "C:/Program Files/SAS/SASFoundation/9.4"
filepath <- "./data"
# filename should be no more than 8 characters, without extension
fileName <- "dumData"
# read data from a SAS dataset
a <- read.ssd(file.path(filepath), fileName,
              sascmd=file.path(sashome, "sas.exe"))
```

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```
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filepath <- "./data"
# filename should be no more than 8 characters, without extension
fileName <- "dumData"
# read data from a SAS dataset
a <- read.ssd(file.path(filepath), fileName,
              sascmd=file.path(sashome, "sas.exe"))
```

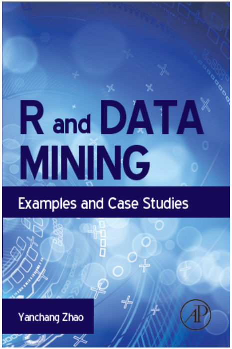
Another way: using function `read.xport()` to read a file in SAS Transport (XPORT) format

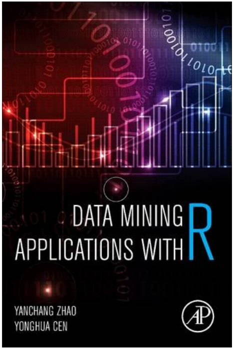
Outline

Online Resources

- Chapter 2: Data Import/Export, in book *R and Data Mining: Examples and Case Studies*
  http://www.rdatamining.com/docs/RDataMining-book.pdf
- RDataMining Reference Card
  http://www.rdatamining.com/docs/RDataMining-reference-card.pdf
- Free online courses and documents
  http://www.rdatamining.com/resources/
- RDataMining Group on LinkedIn (26,000+ members)
  http://group.rdatamining.com
- Twitter (3,300+ followers)
  @RDataMining

The End





Thanks!

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