# MFE R Programming Workshop

## Week 5

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# Introduction

# Questions

Any questions before we start?

# Overview of Week 2

- Some random R tricks
- Importing Data from Databases
- Importing Data from the Web
- Importing Data from WRDS
- `data.table`

# Random R Tricks

# Send an Email from R

```r
library(gmailr)
hiFromR <- mime(
  To = "someone@anderson.ucla.edu",
  From = "me@gmail.com",
  Subject = "hello from R",
  Body = "I am writting you from R."
) %>%
attach_file("./file.R")
send_message(hiFromR)
```

# Working with Files in R

```r
dir.exists("week3") # does the directory exist?
dir.create("week4") # create a directory
# download files
download.file(url, destinationfile, method='curl')
untar()  # untar a file
tar()  # tar a file
# display file information
f <- (dir("/path/to/something",
        full.names = TRUE) %>% file.info)
# delete a file (be careful!!)
unlink("/path/to/something")
```

# Importing Data from Databases

# Databases

- A database stores data in table format.
- There a several popular database management systems (DMS):
  - MySQL, PostgreSQL, SQLite, Oracle, Microsoft SQL Server, etc.
- Structured Query Language (SQL) is used maintain and query the database.

# Databases in R

- There are different R packages for each DMS:
  - MySQL = RMySQL
  - PostgreSQL = RPostgreSQL
  - SQLite = RSQLite
  - Oracle = ROracle
  - SQL Server = RSQLServer
- The functions we use to interact with the database are specified in the R package DBI.

# A MySQL Example: Establish a Connection

- First, we need to establish a connection to the database.

```r
library(DBI)
con <- dbConnect(RMySQL::MySQL(), # the MySQL driver
                 dbname = "dbname", # database name
                 host = "IP_or_WebAddress",
                 port = 3306, # port is 3306 by default
                 user = "username",
                 password = "password")
```

# List and Import Tables

```r
# lists the tables in the database
dbListTables(con)
# returns a dataframe
dbReadTable(con, "tablename")
# import all the tables
table_names <- dbListTables(con)
tables <- lapply(table_names, dbReadTable, conn = con)
# close the connection when you are done
dbDisconnect(con)
```

# Importing Data From the Web

# JSON

- JSON object: an unordered collection of name-value pairs.
- JSON array: an ordered sequence of zero or more values.
- JSON objects and arrays can be nested in each other.
- R handles JSON with the `jsonlite` package.

# An Example with ’jsonlite‘

- Let’s get the current wind and delay status at LAX.

```r
library(jsonlite)
airportCode <- "LAX"
url <- paste0("http://services.faa.gov/airport/status/",
              airportCode)
LAX <- fromJSON(url)
LAX$weather$wind
```

```
## [1] "East at 5.8mph"
```

```r
LAX$delay
```

```
## [1] "false"
```

# Quandl

- Quandl is a useful source of financial data and there is an R package `Quandl` to import the data into R.
- See https://www.quandl.com/tools/r.
- Data can be downloaded as xts objects, datatables, etc.

```r
library(Quandl)
# download GDP as an xts object
gdp <- Quandl("FRED/GDP", type="xts")
last(gdp, 2)
```

# Importing Data from WRDS

# WRDS, CRSP, and R

- Wharton Research Data Services has over 250 terabytes of data.
- One data provider is The Center for Research in Security Prices (CRSP).
    - You will use CRSP data throughout the MFE program.
- I will show you how to access WRDS from R.
- Documentation: Using R with WRDS

# Setup

- First, we need to obtain access to WRDS and download the SAS drivers for JDBC from here.
- The two files should be saved locally.
- Take note of the path to the files; we need the path to establish the connection to WRDS.

# Establish the Connection

```
# ---- INPUTS ---- #
username <- "myUserName"
password <- "myPassword"
# local path to the sas files
sasPath <- "C:/Users/myUser/Documents/wrds-drivers"
# ---- CODE ---- #
library(rJava)
options(java.parameters = '-Xmx4g')
library(RJDBC)
sasCore <- paste0(sasPath, "/sas.core.jar")
sasDriver <- paste0(sasPath, "/sas.intrnet.javatools.jar")
.jaddClassPath(c(sasCore, sasDriver))
driver <- RJDBC::JDBC(
         "com.sas.net.sharenet.ShareNetDriver",
          sasDriver, identifier.quote = "`")
wrds <- RJDBC::dbConnect(driver,
"jdbc:sharenet://wrds-cloud.wharton.upenn.edu:8551/",
 username, password)
```

# Accessing Data

- On the previous slide, we created the connection `wrds`.

```
res <- dbSendQuery(wrds, "select * from DATASET")
data <- fetch(res, n = -1)
data
```

- **`dbSendQuery()`** uses `wrds` to submit the SQL query string to WRDS, which then returns the result `res`.
- **`select * from DATASET`** is a SAS SQL query.
  - See the SAS SQL Documentation for more information.
- **`fetch()`** fetches the actual data based on the result `res`.
- **`n = -1`** is a parameter that determines how many observations to download.
  - `n = -1` specifies that we'd like unlimited observations returned.
  - `n = 10` would limit the number of observations returned to 10.

# Example: S&P 500 Returns

```r
sql <- "SELECT caldt, vwretd FROM CRSPQ.MSP500"
res <- dbSendQuery(wrds, sql)
dbHasCompleted(res) #check that this is true
msp500 <- fetch(res, n = -1)
dbClearResult(res) # free up memory
msp500$caldt <- as.Date(msp500$caldt)
library(xts)
msp500 <- xts::xts(msp500[, -1],
                   order.by = msp500$caldt)
colnames(msp500) <- "vwretd"
```

# data.table

# What is a data.table?

- Think of data.table as an advanced version of data.frame.
    - Every column is the same length, but may have a different type
- It inherits from data.frame and works perfectly even when data.frame syntax is applied on data.table.
- data.table is very fast.
- The syntax of data.table is very concise.
    - Lowers programmer time...
    - ...but it can be hard to understand
    - Make sure you comment your code!
- Highly recommend going through data.table Cheat Sheet.

```
library(data.table)
```

# Creating a data.table

```r
DT <- data.table(A=1:6, B=c("a", "b", "c"),
                 C=runif(6), D=FALSE)
DT
```

```
##    A B         C     D
## 1: 1 a 0.7945419 FALSE
## 2: 2 b 0.4967503 FALSE
## 3: 3 c 0.8702129 FALSE
## 4: 4 a 0.4480231 FALSE
## 5: 5 b 0.0179958 FALSE
## 6: 6 c 0.6264412 FALSE
```

# Selecting Rows by Number in **i**

- The comma is optional.

```
DT[2:4, ]
```

```
##    A B         C     D
## 1: 2 b 0.4967503 FALSE
## 2: 3 c 0.8702129 FALSE
## 3: 4 a 0.4480231 FALSE
```

```
DT[2:4]
```

```
##    A B         C     D
## 1: 2 b 0.4967503 FALSE
## 2: 3 c 0.8702129 FALSE
## 3: 4 a 0.4480231 FALSE
```

# Selecting Columns in **j**

- Columns are specified as a list with the actual names, not as character vectors.
- `.()` is an alias to `list()` in data.tables.

```
DT[2:3, list(A, C)]
```

```
##    A         C
## 1: 2 0.4967503
## 2: 3 0.8702129
```

```
DT[2:3, .(A, C)]
```

```
##    A         C
## 1: 2 0.4967503
## 2: 3 0.8702129
```

# Selecting Columns in **j** with character vectors

- To select columns with a character vector, set the `with` argument to `FALSE`.

```
DT[2:3, c("A", "C"), with=FALSE]
```

```
##     A         C
## 1: 2 0.4967503
## 2: 3 0.8702129
```

# Computing on Columns

- If the lengths of the results are not equal, the shorter one will be recycled.

```
DT[, .(Total = sum(A), Mean = mean(C))]
```

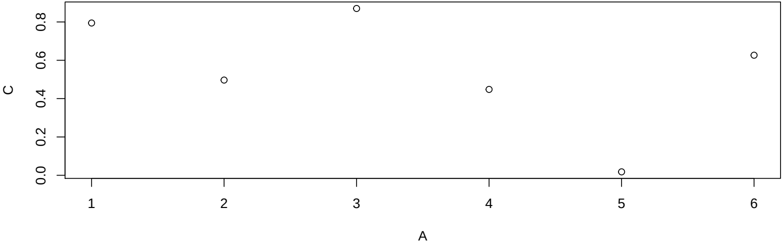
```
##    Total      Mean
## 1:    21 0.5423275
```

```
DT[2:4, .(B, Mean = mean(C))]
```

```
##    B      Mean
## 1: b 0.6049954
## 2: c 0.6049954
## 3: a 0.6049954
```

# You can put almost anything into **j**

```
DT[, plot(A, C)]
```

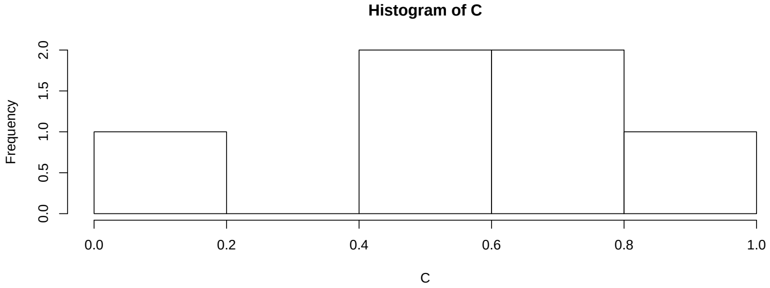


```
## NULL
```

# Multiple Expressions Go in Curly Braces

```
DT[, {print(A)
      hist(C)
      NULL}] # set return value to NULL
```

```
## [1] 1 2 3 4 5 6
```



```
## NULL
```

# Returning a Vector.

```
DT[, .(A)]  # a data.table
```

```
##    A
## 1: 1
## 2: 2
## 3: 3
## 4: 4
## 5: 5
## 6: 6
```

```
DT[, A]  # a vector
```

```
## [1] 1 2 3 4 5 6
```

# Doing **j** by Group

```
DT[, .(Total = sum(A),
      Mean = mean(C)),
      by = .(B)] # returned in the order they appear
```

```
##    B Total      Mean
## 1: a     5 0.6212825
## 2: b     7 0.2573730
## 3: c     9 0.7483271
```

```
# functions work as well
DT[, .(Total = sum(C)), by = .(Group = A%%2)]
```

```
##    Group    Total
## 1:     1 1.682751
## 2:     0 1.571215
```

# .N

- .N, when used inside square brackets, contains the number of rows.
- When put in **j**, .N counts the observations in each group.

```
DT[.N] # the last row, the same as DT[nrow(DT)]
```

```
##    A B         C     D
## 1: 6 c 0.6264412 FALSE
```

```
DT[, .(Total = sum(C), Count = .N), by = .(Group = A%%2)]
```

```
##    Group    Total Count
## 1:     1 1.682751     3
## 2:     0 1.571215     3
```

# Subset of Data - `.SD`

- `.SD` is a data.table.
- `.SD` holds all the columns except for the one specified in **by**, and `.SD` is only accessible in **j**.
- This is very useful if you have a very wide data.table.
- `.SDcols` allows you to apply a function to a subset of the columns.

```r
DT <- as.data.table(mtcars)
DT[, lapply(.SD, median), by = cyl,
    .SDcols = c("mpg","gear","wt")]
```

```
##     cyl  mpg gear    wt
## 1:    6 19.7    4 3.215
## 2:    4 26.0    4 2.200
## 3:    8 15.2    3 3.755
```

- Since `lapply` returns a list, we don't need to wrap it in `.()`.

# Add or Update Columns by Reference Using :=

```r
DT <- data.table(A=1:3, B=4:6)
DT
```

```
##    A B
## 1: 1 4
## 2: 2 5
## 3: 3 6
```

```r
DT[, c("A", "C") := .(rev(A), 7:9)]
```

# Create Multiple Columns with := in One Statement

```
DT <- data.table(mtcars)[, .(mpg, cyl)]
DT[, `:=`(avg = mean(mpg), med = median(mpg)), by = cyl]
head(DT)
```

```
##     mpg cyl      avg  med
## 1: 21.0   6 19.74286 19.7
## 2: 21.0   6 19.74286 19.7
## 3: 22.8   4 26.66364 26.0
## 4: 21.4   6 19.74286 19.7
## 5: 18.7   8 15.10000 15.2
## 6: 18.1   6 19.74286 19.7
```

# Remove Columns Using :=

- We use NULL to remove columns.

```
DT[, D := 10:12]
```

```
## Warning in `[.data.table`(DT, , `:=`(D, 10:12)): Supplie
## assigned to 32 items of column 'D' (recycled leaving rem
```

```
DT[, c("B", "C") := NULL]
```

```
## Warning in `[.data.table`(DT, , `:=`(c("B", "C"), NULL))
## 'B' then assigning NULL (deleting it).

## Warning in `[.data.table`(DT, , `:=`(c("B", "C"), NULL))
## 'C' then assigning NULL (deleting it).
```

- Wrap the LHS in () if you pass a variable.

# Combining := with **i** and **by**

```r
DT <- data.table(A=1:6, B=c("a", "b", "c"), C=runif(6))
DT[1:5, D := sum(C), by=B]
```

# Use set() in Loops.

- set() is a loopable, low-overhead version, of the := operator, but it cannot handle grouping.
- Syntax: set(DT, i, j, value).
- Instead of for (i in 1:6) DT[i, z := i+1] we can

```
DT <- data.table(A=7:12, B=7:12)
for (i in 1:6) set(DT, i, 2L, i+1)
DT
```

```
##       A B
## 1:  7 2
## 2:  8 3
## 3:  9 4
## 4: 10 5
## 5: 11 6
## 6: 12 7
```

# setnames() to Change the Column Names

- setnames(DT, "old", "new") changes the column names by reference (no copies are being made).

```
setnames(DT,c("A", "B"),c("X", "Y"))
DT
```

```
##      X Y
## 1:  7 2
## 2:  8 3
## 3:  9 4
## 4: 10 5
## 5: 11 6
## 6: 12 7
```

# setcolorder() Reorders the Columns by Reference

```
setcolorder(DT,c("Y", "X"))
DT
```

```
##    Y  X
## 1: 2  7
## 2: 3  8
## 3: 4  9
## 4: 5 10
## 5: 6 11
## 6: 7 12
```

# Using Column Names in **i**

```r
DT <- data.table(A=1:6, B=c("a", "b", "c"),
                 C=runif(6), D=FALSE)
DT[B %in% c("a","b")]
```

```
##    A B         C     D
## 1: 1 a 0.4903614 FALSE
## 2: 2 b 0.3080525 FALSE
## 3: 4 a 0.6153089 FALSE
## 4: 5 b 0.9269470 FALSE
```

# Regular Expressions

- Metacharacters allow you to match certain types of characters.
    - For example, . means any single character, ^ means “begins with”, and $ means “ends with”.
- If you want to use any of the metacharacters as actual text, you need to use the \ escape sequence.
- See ?gsub() and ?grep().

```
iris <- as.data.table(iris)
# Change column names
setnames(iris, names(iris), gsub("^Sepal\\.", "", names(iri
# Remove columns
iris[, grep("^Petal", names(iris)) := NULL]
```

# Keys

- Setting a key sorts the table by the column specified.

```
DT <- data.table(A=c("c", "b", "a"),B=1:6)
setkey(DT, A)
DT
```

```
##    A B
## 1: a 3
## 2: a 6
## 3: b 2
## 4: b 5
## 5: c 1
## 6: c 4
```

# Keys as Row Names

- Keys can be used like row names.

```
DT["a"]
```

```
##    A B
## 1: a 3
## 2: a 6
```

```
DT["a", mult = "first"]
```

```
##    A B
## 1: a 3
```

```
DT["a", mult = "last"]
```

```
##    A B
## 1: a 6
```

# nomatch

- Keys can be used like row names.

```r
DT[c("a","d")]
```

```
##    A  B
## 1: a  3
## 2: a  6
## 3: d NA
```

```r
DT[c("a","d"), nomatch = 0]
```

```
##    A B
## 1: a 3
## 2: a 6
```

# Multi-Column Keys

- Use `.()` to select rows.

```
DT <- data.table(A=c("c", "b", "a"),B=1:6,C=7:12)
setkey(DT, A, B)
DT[.("b")]
```

```
##    A B  C
## 1: b 2  8
## 2: b 5 11
```

```
DT[.("b", 5)]
```

```
##    A B  C
## 1: b 5 11
```

# Using shift for to lead/lag vectors and lists

```
DT <- data.table(mtcars)[,.(mpg)]
DT[,mpg_lag1:=shift(mpg, n = 1)]
DT[,mpg_forward1:=shift(mpg, n = 1, type='lead')]
head(DT)
```

```
##     mpg mpg_lag1 mpg_forward1
## 1: 21.0       NA         21.0
## 2: 21.0     21.0         22.8
## 3: 22.8     21.0         21.4
## 4: 21.4     22.8         18.7
## 5: 18.7     21.4         18.1
## 6: 18.1     18.7         14.3
```

# Reshaping data.tables

- The melt and dcast functions for data.tables are extensions of the corresponding functions from the reshape2 package.

```
DT <- readRDS("melt_example.RDS")
DT
```

```
##    fam_id age_mom dob_child1 dob_child2 dob_child3
## 1:      1      30 11/26/1998  1/29/2000         NA
## 2:      2      27   6/2/1996         NA         NA
## 3:      3      26  7/11/2002   4/5/2004  7/20/2007
## 4:      4      32 10/10/2004  8/27/2009   2/1/2012
## 5:      5      29  12/5/2000  2/28/2005         NA
```

# melting data.tables (wide to long)

```
DT.m1 <- melt(DT,
              id.vars = c("fam_id", "age_mom"),
              measure.vars = c("dob_child1", "dob_child2",
DT.m1
```

```
##     fam_id age_mom   variable      value
##  1:      1      30 dob_child1 11/26/1998
##  2:      2      27 dob_child1   6/2/1996
##  3:      3      26 dob_child1  7/11/2002
##  4:      4      32 dob_child1 10/10/2004
##  5:      5      29 dob_child1  12/5/2000
##  6:      1      30 dob_child2  1/29/2000
##  7:      2      27 dob_child2         NA
##  8:      3      26 dob_child2   4/5/2004
##  9:      4      32 dob_child2  8/27/2009
## 10:      5      29 dob_child2  2/28/2005
## 11:      1      30 dob_child3         NA
## 12:      2      27 dob_child3         NA
```

# Casting data.tables (long to wide)

```
dcast(DT.m1, fam_id + age_mom ~ variable,
      value.var = "value")
```

```
##    fam_id age_mom dob_child1 dob_child2 dob_child3
## 1:      1      30 11/26/1998  1/29/2000         NA
## 2:      2      27   6/2/1996         NA         NA
## 3:      3      26  7/11/2002   4/5/2004  7/20/2007
## 4:      4      32 10/10/2004  8/27/2009   2/1/2012
## 5:      5      29  12/5/2000  2/28/2005         NA
```

# fread and fwrite

- fread is similar to read.csv() and but a lot faster. It reads a csv file into a data.table.
- fwrite is to write a data.table into a csv file similar to write.csv().

# Converting xts objects to data.tables

```r
library(xts)
x <- matrix(1:4, nrow=2, ncol=2)
idx <- seq(as.Date("2016-10-31"), length=2, by="months")
x_xts <- xts(x, order.by = idx)
x_xts
```

```
##            [,1] [,2]
## 2016-10-31    1    3
## 2016-12-01    2    4
```

```r
colnames(x_xts) <- c("a", "b")
DT <- as.data.table(x_xts)
setkey(DT,index)
DT
```

```
##         index a b
## 1: 2016-10-31 1 3
## 2: 2016-12-01 2 4
```

# Rolling Joins

- Rolling joins are useful for time-series data.
- See `rollends` in `?data.table`.

```r
DT
```

```
##         index a b
## 1: 2016-10-31 1 3
## 2: 2016-12-01 2 4
```

```r
dt <- as.Date("2016-11-15"); DT[.(dt)]
```

```
##         index  a  b
## 1: 2016-11-15 NA NA
```

```r
DT[.(dt), roll=TRUE] # roll forward; try roll=-Inf.
```

```
##         index a b
## 1: 2016-11-15 1 3
```

# Lab 3

Let’s work on Lab 3.