STAT 3690 Lecture Note

Part I: R and matrix basics

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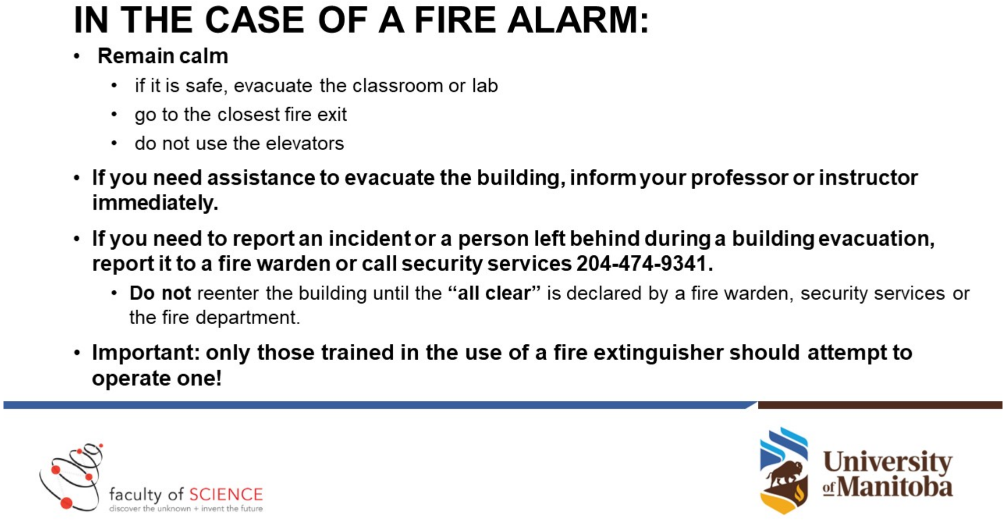

IN THE CASE OF A FIRE ALARM:

- **Remain calm**
  - if it is safe, evacuate the classroom or lab
  - go to the closest fire exit
  - do not use the elevators
- **If you need assistance to evacuate the building, inform your professor or instructor immediately.**
- **If you need to report an incident or a person left behind during a building evacuation, report it to a fire warden or call security services 204-474-9341.**
  - **Do not** reenter the building until the **"all clear"** is declared by a fire warden, security services or the fire department.
- **Important: only those trained in the use of a fire extinguisher should attempt to operate one!**

Syllabus

Contact

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Timeline

- Lectures
  - Mon/Wed/Fri 9:30–10:20 am
- Office Hour
  - Wed 10:30–11:30 am
- Assessments
  - 4 or 5 Assignments
  - Midterm
  - Final project

Grading

- Assignments (30%)
  - Scanned/photographed and submitted to Crowdmark
  - Attaching both outputs and source codes (if applicable)
  - Including necessary interpretation
  - Organized in a clear and readable way
  - Accepting NO late submission
- Midterm (35%)
  - Open-book
  - In-person on Mar 10 6–8 pm OR take-home (webcam-invigilated) NOT later than Mar. 20
- Final project (35%)
  - Individual report analying recently collected datasets
  - See the Project Guideline posted at UM Learn

Materials

- Reading list (recommended but not required)
  - [J&W] R. A. Johnson & D. W. Wichern. (2007). *Applied Multivariate Statistical Analysis*, 5/6th Ed. London: Pearson Education.
    * 2HR print reserve in the Sciences and Technology Library
  - [R&C] A. C. Rencher & W. F. Christensen. (2012). *Methods of Multivariate Analysis*, 3rd Ed. Hoboken: Wiley.
    * Digital copy accessible via the library
  - D. Salsburg (2001). *The Lady Tasting Tea: How Statistics Revolutionized Science in the Twentieth Century*. New York: WH Freeman.
- Lecture notes and beyond
  - zhiyanggeezhou.github.io
  - UM Learn

Outline

- Topics to be covered
  - Matrix manipulation
  - Basics of statistical modeling
  - Multivariate normal distribution
  - Inference on a mean vector
  - Comparisons of several multivariate means
  - Multivariate linear regression
  - Principal component analysis
  - Factor analysis
  - Canonical correlation analysis
  - and so forth

R basics

- Installation
  - download and install BASE *R* from https://cran.r-project.org
  - download and install *Rstudio* from https://www.rstudio.com
  - download and install packages via *Rstudio*
- Working directory
  - When you ask *R* to open a certain file, it will look in the working directory for this file.
  - When you tell *R* to save a data file or figure, it will save it in the working directory.

```r
getwd()
mainDir <- "c:/"
subDir <- "stat3690"
dir.create(file.path(mainDir, subDir), showWarnings = FALSE)
setwd(file.path(mainDir, subDir))
```

- Packages
  - installation: install.packages()
  - loading: library()

```r
install.packages('nlme')
library(nlme)
```

- Help manual: help(), ?, google, stackoverflow, etc.

- *R* is free but not cheap
  - Open-source
  - Citing packages
  - NO quality control
  - Requiring statistical sophistication
  - Time-consuming to become a master

- References for *R*
  - M. L. Rizzo (2019) Statistical Computing with R, 2nd Ed. (forthcoming)
  - O. Jones, R. Maillardet, A. Robinson (2014) Introduction to Scientific Programming and Simulation Using R, 2nd Ed.
  - ……
- Courses online
  - https://www.pluralsight.com/search?q=R
  - ……
- Data types: let str() or class() tell you
  - numbers (integer, real, or complex)
  - characters (“abc”)
  - logical (TRUE or FALSE)
  - date & time
  - factor (commonly encountered in this course)
  - NA (different from Inf, “ ’’, 0, NaN etc.)

- Data structures: let str() or class() tell you
  - vector: an ordered collection of the same data type
  - matrix: two-dimensional collection of the same data type
  - array: more than two dimensional collection of the same data type
  - data frame: collection of vectors of same length but of arbitrary data types
  - list: collection of arbitrary objects

- Data input and output
  - create
    - vector: c(), seq(), rep()
    - matrix: matrix(), cbind(), rbind()
    - data frame

  - output: write.table(), write.csv(), write.xlsx()
  - import: read.table(), read.csv(), read.xlsx()
    * header: whether or not assume variable names in first row
    * stringsAsFactors: whether or not convert character string to factors
  - scan(): a more general way to input data
  - save.image() and load(): save and reload workspace
  - source(): run R script

- Parenthesis in *R*
  - paenthesis () to enclose inputs for functions
  - square brackets [], [[]] for indexing
  - braces {} to enclose forloop or statements such as if or ifelse

---

```r
# Create numeric vectors
v1 = c(1,2,3); v1
v2 = seq(4,6,by=0.5); v2
v3 = c(v1,v2); v3
v4 = rep(pi,5); v4
v5 = rep(v1,2); v5
v6 = rep(v1,each=2); v6
# Create Character vector
v7 <- c("one", "two", "three"); v7
# Select specific elements
v1[c(1,3)]
v7[2]
```

```r
# Create matrices
m1 = matrix(-1:4, nrow=2); m1
m2 = matrix(-1:4, nrow=2, byrow=TRUE); m2
m3 = cbind(m1,m2); m3
(m4 = cbind(m1,m2))
```

```r
# Create a data frame
e <- c(1,2,3,4)
f <- c("red", "white", "black", NA)
g <- c(TRUE,TRUE,TRUE,FALSE)
mydata <- data.frame(e,f,g)
names(mydata) <- c("ID", "Color", "Passed") # name variable
mydata
```

```r
# Output
write.csv(mydata, file='mydata.csv', row.names=F)
```

```r
# Import
(simple = read.csv('mydata.csv', header=TRUE, stringsAsFactors=TRUE))
class(simple)
class(simple[[1]])
class(simple[[2]])
class(simple[[3]])
(simple = read.csv('mydata.csv', header=FALSE, stringsAsFactors=FALSE))
class(simple[[3]])
```

```r
# EXERCISE
# Create a matrix with 2 rows and 6 columns such that it contains the numbers 1,4,7,...,34.
# Make sure the numbers are increasing row-wise; ie, 4 should be in the second column.
# Use the seq() function to generate the numbers. Do NOT type them out by hand!
```

```r
# ANSWER
matrix(seq(from=1, to=34, by=3), nrow=2)
```

- Elementary arithmetic operators
  - +, -, *, /, ^
  - log, exp, sin, cos, tan, sqrt
  - FALSE and TRUE becoming 0 and 1, respectively
  - sum(), mean(), median(), min(), max(), var(), sd(), summary()
- Matrix calculation
  - element-wise multiplication: A * B
  - matrix multiplication: A %*% B
  - singlar value decomposition: eigen(A)
- Loops: for() and while()

- Probabilities
  - normal distribution: dnorm(), pnorm(), qnorm(), rnorm()
  - uniform distribution: dunif(), punif(), qunif(), runif()
  - multivariate normal distribution: dmvnorm(), rmvnorm()

```r
# Generate two datasets
set.seed(100)
x = rnorm(250, mean=0, sd=1)
y = runif(250, -3, 3)
```

- Basic plots
  - strip chart, histogram, box plot, scatter plot
  - Package ggplot2 (RECOMMENDED)

```r
# Strip chart
stripchart(x)

# Histogram
hist(x)

# Box plot
boxplot(x)

# Side-bu-side box plot
xy = data.frame(normal=x, uniform=y)
boxplot(xy)

# Scatter Plot with fitted line
plot(x, y ,xlab="x", ylab = "y", main = "scatter plot between x and y")
abline(lm(y~x))
```

```
# EXERCISE
# Play with a data set called "Gasoline" included in the package "nlme".
# 1. How many variables are contained in this data set? What are they?
# 2. Generate a histogram of yield and calculate the five number summary for it.
#   What is the shape of the histogram?
# 3. Generate side-by-side boxplots,
#   comparing the temperature at which all the gasoline is vaporized (endpoint) to sample.
#   Does it seem that the temperatures at which all the gasoline is vaporized differ by sample?
# 4. Generate a plot that illustrates the relationship between yield and endpoint.
#   Describe the relationship between these two variables.
# 5. What if the plot created in Q4 were separated by sample?
#   Generate a plot of yield v.s. endpoint, separated by sample.
```

```
# ANSWER
attach(nlme::Gasoline)
# 1. Six variables: yield, endpoint, sample, API, vapor, ASTM
# 2.
summary(yield)
hist(yield, nclass=50)
# 3.
boxplot(endpoint ~ Sample)
anova(lm(endpoint ~ Sample))
# 4.
plot(x=endpoint, y=yield, xlab="endpoint",ylab = "yield",
      main = "scatter plot between endpoint and yield")
abline(lm(yield~endpoint))
# 5.
par(mfrow=c(2,5))
for (i in 1:10){
  plot(x=endpoint[Sample==i], y=yield[Sample==i], xlab='', ylab='', main=paste('Sample=', i))
  abline(lm(yield[Sample==i]~endpoint[Sample==i]))
}
# Do not forget to detach the dataset after using it.
detach(nlme::Gasoline)
```