Data Analysis and Visualisation using R

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Outline of Topics I

Outline of Topics II

- Data Frames
- Factors
- List
- Basic datastucture functions

3. Working with Data
   - Reading Data
   - Transforming Data
   - Live example

4. Visualisation
   - Introduction
   - Basic plots
   - Advanced Plots

Outline of Topics III

- Grammar of Graphics

5. Webapps
    - Introduction to Shiny
    - Features
    - Architecture
    - Code example

6. Integration with other Systems

Outline

What is R ?

Wikipedia

R is a free software programming language and a software environment for statistical computing and graphics. The R language is widely used among statisticians and data miners for developing statistical software and data analysis.

Why use R ?

- Designed and optimised for data processing
- Lots of modules
- State of the art graphics
- Free as in freedom/beer
- Helpful community
- Very flexible and good integration

R Studio Installation

- Go to RStudio website
- Download the server/desktop version
- For server - Open the browser and go to http://127.0.0.1:8787
- For desktop - Click on the shortcut and you are ready to go

R Studio Basics

- The Source Editor
- The Console / Interpreter
- Workspace / History
- Plots / Packages / Help

Basics - Starting off and getting help

- Starting the interpreter
- Getting online help - ? or help()
- Searching for help - ??
- Approximate search - apropos()

Basics - Objects and Workspaces

- attach(object)
- detach(object)
- rm()
- save.image("ExploreData.RData")
- load("SavedWorkspace.RData")
- save(data1,data2,file="SavedWorkspace.RData")

Basics - Using inbuilt function

- str
- summary
- head
- View
- Assignment <-
- source
- sink

Basics - str function

```
## str function demo
str(mtcars)

## 'data.frame': 32 obs. of  11 variables:
##  $ mpg : num  21 21 22.8 21.4 18.7 18.1 14.3 24.4 22.8 19.2 ...
##  $ cyl : num  6 6 4 6 8 6 8 4 4 6 ...
##  $ disp: num  160 160 108 258 360 ...
##  $ hp  : num  110 110 93 110 175 105 245 62 95 123 ...
##  $ drat: num  3.9 3.9 3.85 3.08 3.15 2.76 3.21 3.69 3.92 3.92 ...
##  $ wt  : num  2.62 2.88 2.32 3.21 3.44 ...
##  $ qsec: num  16.5 17 18.6 19.4 17 ...
##  $ vs  : num  0 0 1 1 0 1 0 1 1 1 ...
##  $ am  : num  1 1 1 0 0 0 0 0 0 0 ...
##  $ gear: num  4 4 4 3 3 3 3 4 4 4 ...
##  $ carb: num  4 4 1 1 2 1 4 2 2 4 ...
```

Basics - summary function

```
## summary function demo
summary(mtcars)

##       mpg             cyl             disp             hp
##  Min.   :10.4   Min.   :4.00   Min.   : 71.1   Min.   : 52.0
##  1st Qu.:15.4   1st Qu.:4.00   1st Qu.:120.8   1st Qu.: 96.5
##  Median :19.2   Median :6.00   Median :196.3   Median :123.0
##  Mean   :20.1   Mean   :6.19   Mean   :230.7   Mean   :146.7
##  3rd Qu.:22.8   3rd Qu.:8.00   3rd Qu.:326.0   3rd Qu.:180.0
##  Max.   :33.9   Max.   :8.00   Max.   :472.0   Max.   :335.0
##       drat             wt             qsec             vs
##  Min.   :2.76   Min.   :1.51   Min.   :14.5   Min.   :0.000
##  1st Qu.:3.08   1st Qu.:2.58   1st Qu.:16.9   1st Qu.:0.000
##  Median :3.69   Median :3.33   Median :17.7   Median :0.000
##  Mean   :3.60   Mean   :3.22   Mean   :17.8   Mean   :0.438
##  3rd Qu.:3.92   3rd Qu.:3.61   3rd Qu.:18.9   3rd Qu.:1.000
##  Max.   :4.93   Max.   :5.42   Max.   :22.9   Max.   :1.000
```

Basics - head function

```
## head function demo
head(mtcars)

##                    mpg cyl disp  hp drat    wt  qsec vs am gear carb
## Mazda RX4         21.0   6  160 110 3.90 2.620 16.46  0  1    4    4
## Mazda RX4 Wag     21.0   6  160 110 3.90 2.875 17.02  0  1    4    4
## Datsun 710        22.8   4  108  93 3.85 2.320 18.61  1  1    4    1
## Hornet 4 Drive    21.4   6  258 110 3.08 3.215 19.44  1  0    3    1
## Hornet Sportabout 18.7   8  360 175 3.15 3.440 17.02  0  0    3    2
## Valiant           18.1   6  225 105 2.76 3.460 20.22  1  0    3    1
```

Basics - Inbuilt Statistics functions

- mean
- sd
- var
- median
- quantile
- hist
- plot

Basics - Stats Functions Demo

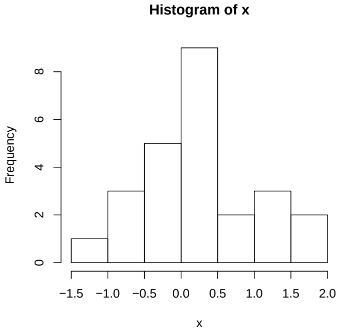
```
set.seed(1729)
x = rnorm(25)
mean(x)

## [1] 0.1951

var(x)

## [1] 0.5624

sd(x)

## [1] 0.7499
```

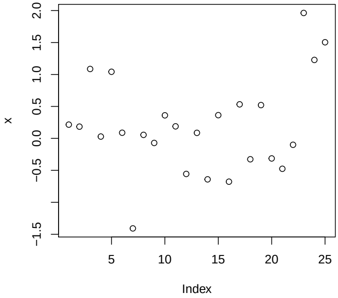
Basics - Stats Functions Demo

```
median(x)

## [1] 0.08827

quantile(x)

##       0%      25%      50%      75%     100%
## -1.40843 -0.31371  0.08827  0.52097  1.96241
```

Basics - Stats Functions Demo

```
hist(x)
plot(x)
```





Basics - Library commands

- install.packages("packagename")
- library("package")
- update.packages("packages")
- search()
- detach("package:packagename")

Install Views

- install.views("packageGroupName")
- update.views("packageGroupName")

Package Groups

- Econometrics
- Graphics
- TimeSeries
- HighPerformanceComputing
- Optimization

Resources

- R Project
- R Seek
- R Documentation
- R Journal
- CRAN

Outline

Vector

Vector Datastructure

Vectors are one-dimensional arrays that can hold numeric data, character data, or logical data. Vectors can be column vectors (created with c()) or row vectors(can be created using the transpose function t()).

Vector - Demo

```
a <- c(1, 4, 3, -1, 0, 2, 9)
b <- c("Apples", "Oranges", "Banana", "Mango")
c <- c(FALSE, TRUE, TRUE, FALSE)
a[4]

## [1] -1

b[c(2, 4)]

## [1] "Oranges" "Mango"

c[2:4]

## [1]  TRUE  TRUE FALSE
```

Matrix

Matrix Datastructure

A matrix is a two-dimensional array where each element has the same mode (numeric, character, or logical). Matrices are created with the matrix() function.

Matrix - Demo 1

```
m1 <- matrix(1:20, nrow = 5, ncol = 4)
m1

##      [,1] [,2] [,3] [,4]
## [1,]    1    6   11   16
## [2,]    2    7   12   17
## [3,]    3    8   13   18
## [4,]    4    9   14   19
## [5,]    5   10   15   20
```

Matrix - Demo 2

```
cells <- c("A","B","C","D","E","F","G","H","I")
rnames <- c("R1", "R2", "R3")
cnames <- c("C1","C2","C3")
m2 <- matrix(cells,nrow=3,ncol=3,byrow=TRUE,
dimnames=list(rnames,cnames))
m2

##    C1  C2  C3
## R1 "A" "B" "C"
## R2 "D" "E" "F"
## R3 "G" "H" "I"
```

Array

Array Datastructure

Arrays are similar to matrices but can have more than two dimensions. Theyre created with an array() function. Like matrices, they can contain only one datatype.

Array - Demo 1

```r
arows <- c("R1", "R2")
acols <- c("C1", "C2", "C3")
azind <- c("Z1", "Z2")
arr <- array(1:12, c(2, 3, 2), dimnames = list(arows, acols, azind))
```

Array - Demo 2

```
arr
```

```
## , , Z1
##
##    C1 C2 C3
## R1  1  3  5
## R2  2  4  6
##
## , , Z2
##
##    C1 C2 C3
## R1  7  9 11
## R2  8 10 12
```

Data Frames

Data Frame Datastructure

A Dataframe is like a matrix but each of the columns can be a different datatype. Another way to think about it is as a bunch of different types of columns with similar keys (like a database table). A dataframe is created with the data.frame() function.

Dataframe Demo 1

```
batname <- c("Sachin", "Sourav", "Rahul", "Laxman")
battype <- c("RHB", "LHB", "RHB", "RHB")
matches <- c(198, 113, 164, 134)
batave <- c(53.86, 42.17, 52.31, 45.97)
batinfo <- data.frame(batname, battype, matches, batave)
batinfo

##   batname battype matches batave
## 1  Sachin     RHB     198  53.86
## 2  Sourav     LHB     113  42.17
## 3   Rahul     RHB     164  52.31
## 4  Laxman     RHB     134  45.97
```

Dataframe Demo 2

```
batinfo$batname

## [1] Sachin Sourav Rahul  Laxman
## Levels: Laxman Rahul Sachin Sourav

batinfo$battype

## [1] RHB LHB RHB RHB
## Levels: LHB RHB

as.numeric(batinfo$battype)

## [1] 2 1 2 2
```

Dataframe Demo 3

```
summary(batinfo)

##    batname   battype    matches          batave
##  Laxman:1   LHB:1    Min.   :113    Min.   :42.2
##  Rahul  :1   RHB:3    1st Qu.:129    1st Qu.:45.0
##  Sachin:1            Median :149    Median :49.1
##  Sourav:1            Mean   :152    Mean   :48.6
##                      3rd Qu.:172    3rd Qu.:52.7
##                      Max.   :198    Max.   :53.9
```

Factors

- Factors are made of categorical data
- Factors can be ordered or unordered
- Factors are represented internally as numbers
- Assignment is by alphabetical order

Factor - Demo 1

```
grades1 <- factor(c("Bad", "Poor", "Average", "Good", "Excellent"))
grades1

## [1] Bad       Poor      Average   Good      Excellent
## Levels: Average Bad Excellent Good Poor

as.numeric(grades1)

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

Factor - Demo 2

```
grades2 <- factor(grades1, order = TRUE, levels = grades1)
grades2

## [1] Bad       Poor      Average   Good      Excellent
## Levels: Bad < Poor < Average < Good < Excellent

as.numeric(grades2)

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

List

List Datastructure

List is a bit of a mixed bag. A list is an ordered collection of objects. A list allows you to gather a variety of (possibly unrelated) objects under one name. A list may contain an arbitrary combination of vectors, matrices, data frames, and even other lists. You create a list using the list() function.

List Demo 1

```
a <- "Hello world"
b <- c(17, 19, 23, 29)
c <- matrix(1:12, nrow = 3)
l <- list(header = a, primes = b, c)
l[[2]]

## [1] 17 19 23 29

l[["primes"]]

## [1] 17 19 23 29
```

List Demo 2

```
l

## $header
## [1] "Hello world"
##
## $primes
## [1] 17 19 23 29
##
## [[3]]
##      [,1] [,2] [,3] [,4]
## [1,]    1    4    7   10
## [2,]    2    5    8   11
## [3,]    3    6    9   12
```

Working with Data Structures

- concatenate c()
- cbind()
- rbind()
- data.frame()
- mode()
- class()

Working with Data Structures

- with()
- sort()
- subset()
- select()
- transform()

Working with Data Structures

- names()
- row.names()
- attributes()

Outline

1. Introduction
2. Data Structures
3. Working with Data
4. Visualisation
5. Webapps
6. Integration with other Systems

Reading data from multiple Sources

- Excel files
- web pages
- csv
- databases

Reading data in Excel files

```
library(gdata)
read.xls("~/hacknight/All_India_Index_April3.xls", sheet = 1)
```

Reading data from HTML tables on the web

```r
library(XML)
url <- "http://en.wikipedia.org/wiki/2011_Cricket_World_Cup_statistics"
tbls <- readHTMLTable(url)
specifictbl <- readHTMLTable(url, which = 3)
```

Reading from csv files

```
stk <- read.csv("~/stackoverflow.csv")
```

Alternatives are read.table(), read.csv2()

Get a subset of data

Using Subset function

```
stkjs <- subset (stk,Tag=="javascript")
stkweb <- subset (stk, Tag=="javascript" | Tag=="html"
| Tag =="css" | Tag=="ajax")
```

An alternative method by column number and names

```
carsmall <- mtcars[1:10, c("mpg", "cyl", "disp", "hp", "drat")]
carsmall <- mtcars[1:10, 1:5]
carstrans <- t(carsmall)
```

Filtering a set of data

```
car400plus <- mtcars[mtcars$displ > 400, ]
carcyl6 <- mtcars[mtcars$cyl == 6, ]
powcars <- mtcars[mtcars$cyl == 8 & mtcars$disp > 400, ]
```

Merging Dataframes

Merging by rows

```
car400 <- mtcars[mtcars$cyl == 8 & mtcars$disp == 400, ]
car400plus <- mtcars[mtcars$cyl == 8 & mtcars$disp > 400, ]
car400all <- merge(car400, car400plus, all = TRUE)
```

Alternative Method using rbind

```
car400all <- rbind(car400, car400plus)
```

Merging Dataframes

Merging by columns

```
carset1 <- mtcars[1:5, c("mpg", "disp")]
carset2 <- mtcars[1:5, c("cyl", "drat")]
merge(carset1, carset2, all = TRUE)  # Does this work ? why ?
merge(carset1, carset2, by = "row.names", all = TRUE)
```

Alternative Method using cbind()

```
carall <- cbind(carset1, carset2)
```

reshape library - melt function

```
stk <- read.csv("~/stackoverflow.txt")
head(stk)
nrow(stk)
stkm <- melt(stk)
head(stkm)
```

reshape library - cast function

```
head(stkm)
stkm$variable <- as.numeric(sub("X","",stkm$variable))
head(stkm)
names(stkm)[2] <- "YearMonth"
head(stkm)
stkc <- cast(stkm, Tag ~ YearMonth)
head(stkc)
```

Making sense of data - A live example

Lets answer these questions

Given the Cars dataset, what is the median/mean mpg of the datapoints by number of cylinders. also what is the number of datapoints we have in each set

Approach 1 - Manual approach - Subset and functions

```
unique(mtcars$cyl)
cyl4 <- subset(mtcars, cyl == 4)
cyl6 <- subset(mtcars, cyl == 6)
cyl8 <- subset(mtcars, cyl == 8)
nrow(cyl4)
nrow(cyl6)
nrow(cyl8)
mean(cyl6$mpg)
mean(cyl4$mpg)
mean(cyl8$mpg)
median(cyl4$mpg)
median(cyl6$mpg)
median(cyl8$mpg)
```

Approach 2 - Get smarter - Use loops

```
ans = data.frame()
for (cylnum in unique(mtcars$cyl)) {
    tmp = subset(mtcars, mtcars$cyl == cylnum)
    count = nrow(tmp)
    mean = mean(tmp$mpg)
    median = median(tmp$mpg)
    ans = rbind(ans, data.frame(cylnum, count, mean, median))
}
```

Approach 3 - Base R - Use *apply functions

```
tapply(mtcars$mpg, mtcars$cyl, FUN = length)
tapply(mtcars$mpg, mtcars$cyl, FUN = mean)
tapply(mtcars$mpg, mtcars$cyl, FUN = median)
```

Approach 4 - Base R - use aggregate function

```r
aggregate(mpg ~ cyl, data = mtcars, FUN = "length")
aggregate(mpg ~ cyl, data = mtcars, FUN = "mean")
aggregate(mpg ~ cyl, data = mtcars, FUN = "median")
```

Approach 5 - doBy Package - use summaryBy function

```
summaryBy(mpg~cyl,data=mtcars,FUN=function(x)
  c(count=length(x), mean=mean(x), median=median(x)))
```

Approach - plyr library - use **ply functions

```
ddply(mtcars,'cyl',function(x)
  c(count=nrow(x), mean=mean(x$mpg), median=median(x$mpg)),
.progress='text')
```

More about the plyr module

plyr is a very useful module for applying functions to different datastructures. The functions in plyr are of the form XYply where 'X' is the Input datatype and 'Y' is the Output datatype So as in the above example, the input datatype was a dataframe and the output datatype is a dataframe. The type and their letter designations are

- a - array
- d - data.frame
- l - list
- m - matrix
- _ - no output returned

Outline

Why Visualisation ?

- Easier to percieve differences easily (Magnitude, Range, Difference)
- Easier to see outliers, anomalier and grouping
- Easy to do exploratory analysis in R
- Easier to build narratives (Picture worth a million numbers)
- Bling !!!

Visualisation Packages

- boxplot, pie, hist from base graphics
- specialized packages like vioplot
- Grammar of Graphics - ggplot2
- lattice

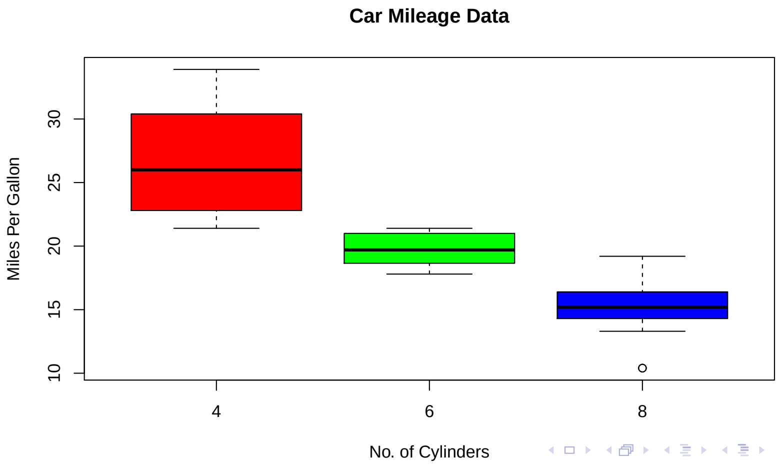
Boxplots

- Good for individual variable or groups of variables
- Good for showing outliers and quartiles ("shape")
- take up less space than a histogram

Boxplot example I

```
boxplot(mpg ~ cyl, data=mtcars, main="Car Mileage Data",
        xlab="No. of Cylinders", ylab="Miles Per Gallon",
        Notch=TRUE, col=rainbow(3))
```

Boxplot example II



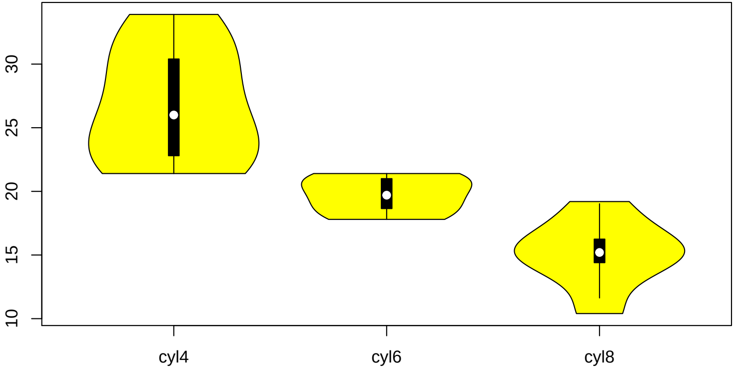
Violin plots

- Similar to boxplots but show probablity density
- Good for showing distribution
- Look like violins hence the name

Violin Plot Example I

```
library(vioplot)

## Loading required package:  sm
## Package 'sm', version 2.2-5:  type help(sm) for summary
information

library(sm)
cyl4 <- subset(mtcars,cyl==4)
cyl6 <- subset(mtcars,cyl==6)
cyl8 <- subset(mtcars,cyl==8)
vioplot::vioplot(cyl4$mpg,cyl6$mpg,cyl8$mpg,
names=c("cyl4","cyl6", "cyl8"), col="yellow")
```

Violin Plot Example II



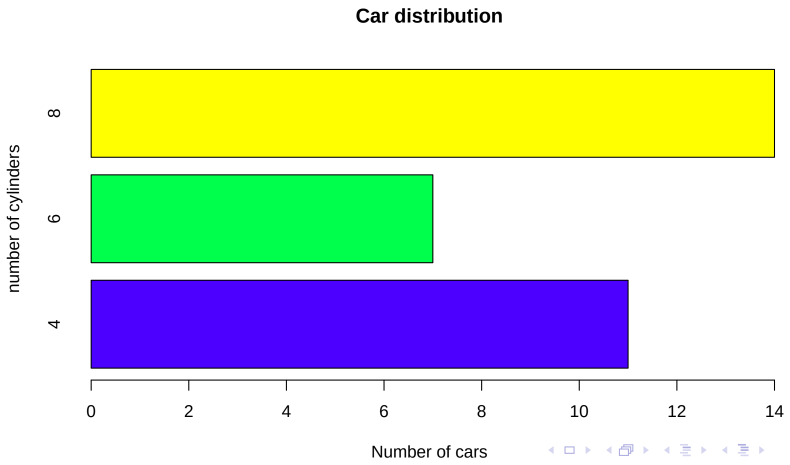
Barplot

- Good to compare relative magnitudes
- Good to compare time series data
- Easier on the eyes

Barplot Example I

```
barplot(table(mtcars$cyl),main="Car distribution",
        ylab="number of cylinders",xlab="Number of cars",
        horiz=TRUE,col=topo.colors(3))
```

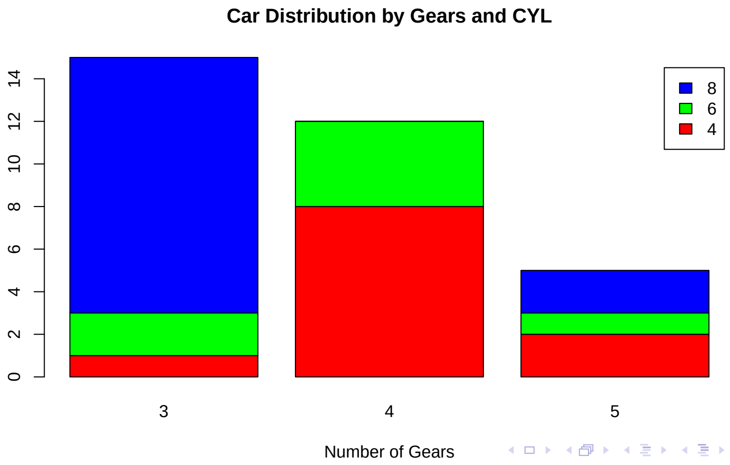
Barplot Example II



Stacked Barplot Example I

```
counts <- table(mtcars$cyl, mtcars$gear)
barplot(counts, main="Car Distribution by Gears and CYL",
        xlab="Number of Gears", col=rainbow(3),
        legend = rownames(counts))
```

Stacked Barplot Example II



Heatmap Example 1

```
# scale data to mean=0, sd=1 and convert to matrix
mtscaled <- as.matrix(scale(mtcars))

# create heatmap and don't reorder columns
heatmap(mtscaled, Colv = F, scale = "none")
```

Heatmap Example 2

```
# cluster rows
hc.rows <- hclust(dist(mtscaled))
plot(hc.rows)

# transpose the matrix and cluster columns
hc.cols <- hclust(dist(t(mtscaled)))

# draw heatmap for first cluster
heatmap(mtscaled[cutree(hc.rows,k=2)==1,],
        Colv=as.dendrogram(hc.cols), scale='none')

# draw heatmap for second cluster
heatmap(mtscaled[cutree(hc.rows,k=2)==2,],
        Colv=as.dendrogram(hc.cols), scale='none')
```

Introduction to ggplot2

- Thinking about dataviz moves away from mechanics to representation
- Allows you to layer graphics and added remove components
- Based on Leland Wilkinson's "The Grammar of Graphics" book
- Allows to compose graphs based on components
- Allows to build beautiful graphs quickly

Components of Graphics - 1

- **Data** - The cleaned up data with all the different variables, factors. This includes the **mappings** to the aesthetic attributes of a plot.
- **Geom** - Geometric objects or geoms represent what you actually see on the screen. This includes lines, splines, points, polygons etc.
- **Stat** - Statistical transformations. These are optional. Examples include binning in a histogram or summarising a 2D relationship with a linear model.

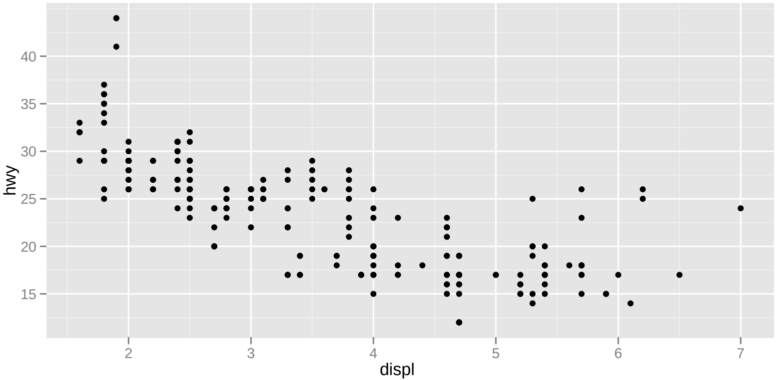
Components of Graphics - 2

- **Scale** - Scales map values in the data into the aesthetic space such as color, size or shape. Scales draw axes and legends to represent what is seen on the screen to the actual underlying data.
- **Coord** - A coordinate sytems that provides a mapping from the data onto the screen. Examples include Cartesian coordinates, map coordinates and polar coordinates.
- **Facet** - A facet gives us a method to break un the data into subsets as well as display these on the screen. Great for increasing infomation density while graphing multidimensional data.

Scatterplot I

```
library(ggplot2)
qplot(displ, hwy, data = mpg)
```

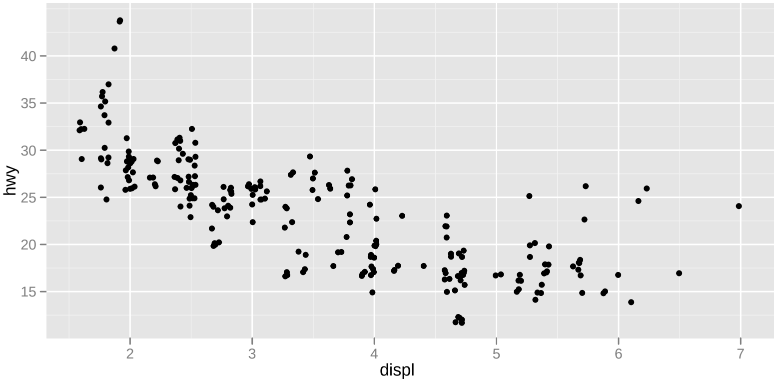
Scatterplot II



Scatterplot I

```r
qplot(displ, hwy, data = mpg, geom = "jitter")
```

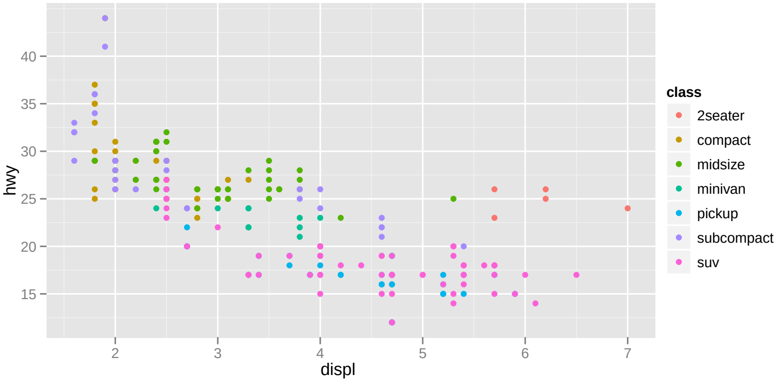
Scatterplot II



Scatterplot I

```
qplot(displ, hwy, data = mpg, color = class)
```

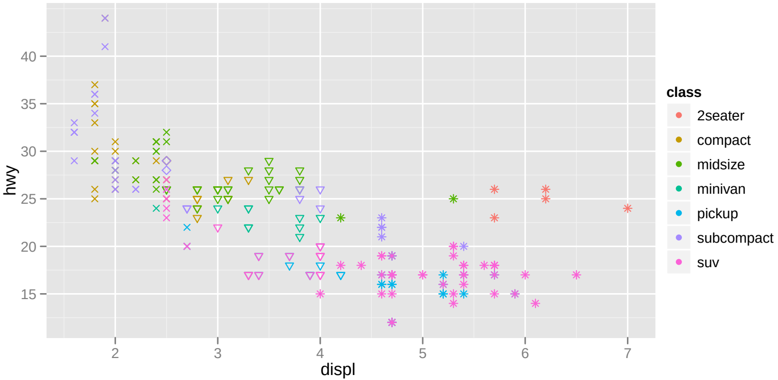
Scatterplot II



Scatterplot I

```
qplot(displ, hwy, data = mpg, color = class, shape = cyl)
```

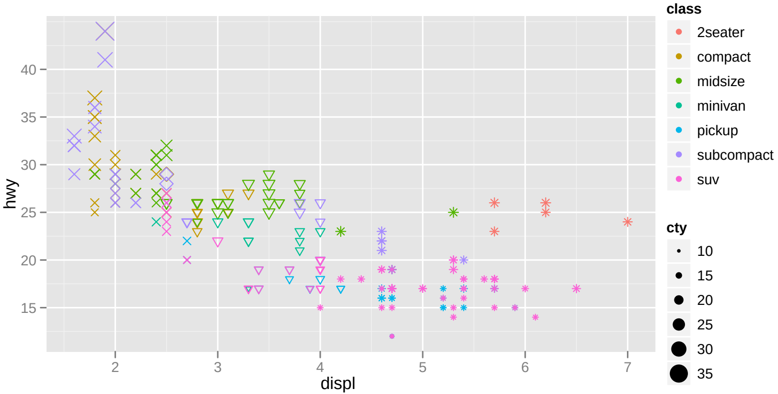
Scatterplot II



Scatterplot I

```
qplot(displ, hwy, data = mpg, color = class, shape = cyl, size = cty)
```

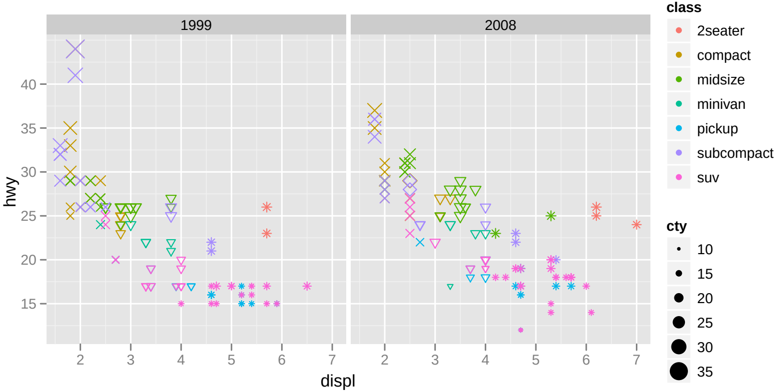
Scatterplot II



Scatterplot I

```
qplot(displ,hwy,data=mpg,color=class,shape=cyl,size=cty)
+ facet_wrap (~year)
```

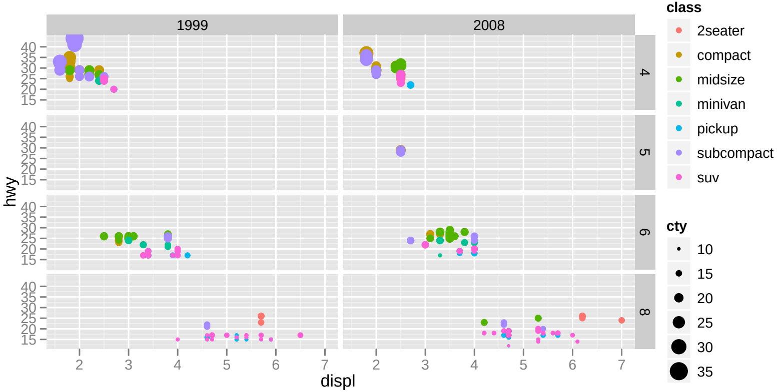
Scatterplot I



Scatterplot I

```
qplot(displ, hwy, data = mpg, color = class, shape = cyl, size = cty)
+facet_wrap(~year)
```

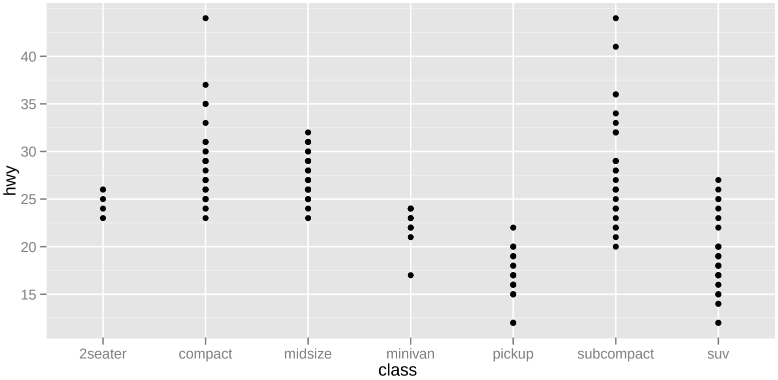
Scatterplot I



Scatterplot 2 I

```r
qplot(class, hwy, data = mpg)
```

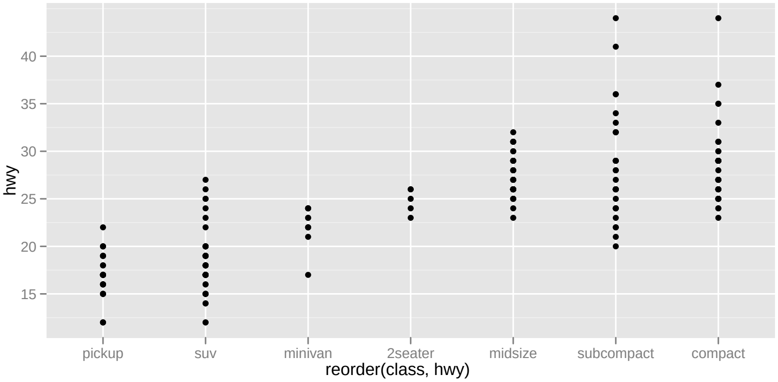
Scatterplot 2 II



Scatterplot 2 I

```
qplot(reorder(class, hwy), hwy, data = mpg)
```

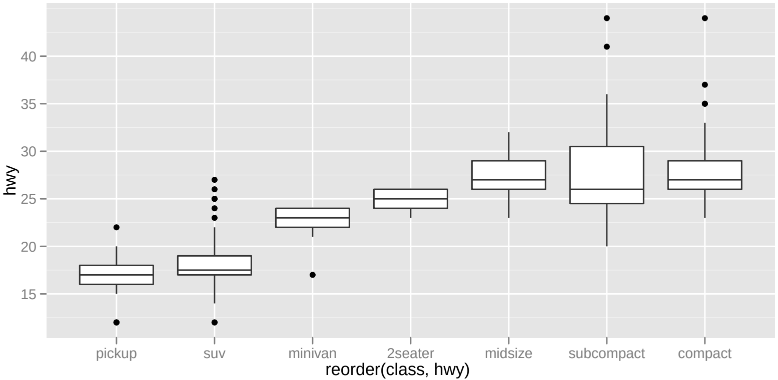
Scatterplot 2 II



Scatterplot 2 I

```
qplot(reorder(class, hwy), hwy, data = mpg, geom="boxplot")
```

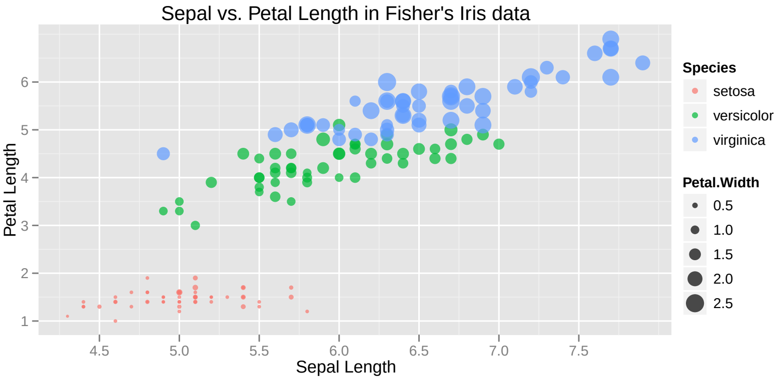
Scatterplot 2 II



Scatterplot 3 I

```
qplot(Sepal.Length, Petal.Length, data = iris, color = Species,
      size = Petal.Width, alpha = I(0.7),
      xlab = "Sepal Length", ylab = "Petal Length",
      main = "Sepal vs. Petal Length in Fisher's Iris data")
```

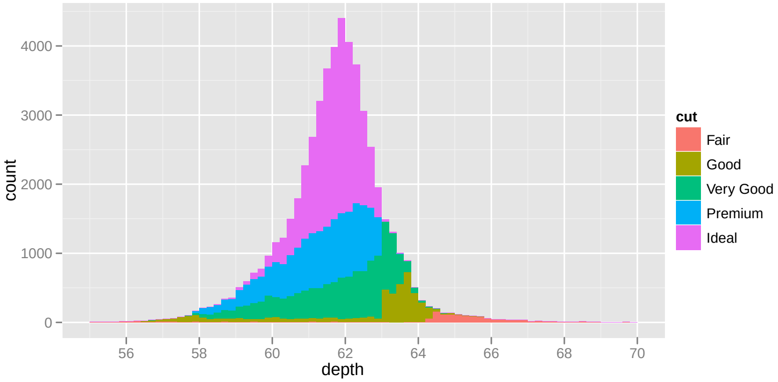
Scatterplot 3 II



Stackedbar Chart I

```
qplot(depth, data = diamonds, binwidth = 0.2, fill = cut) + xlim(55,70)
```

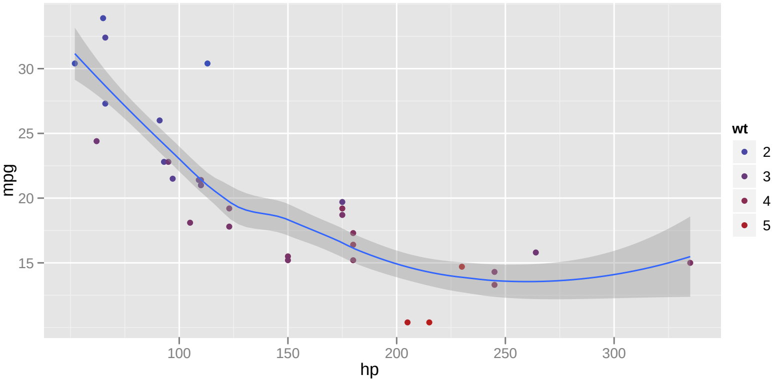
Stackedbar Chart II



Line plot I

```
# Scale + Layering + Aesthetic example
plotl <- ggplot(mtcars, aes(x=hp,y=mpg))
plotl + geom_point(aes(color=wt)) + geom_smooth()
```

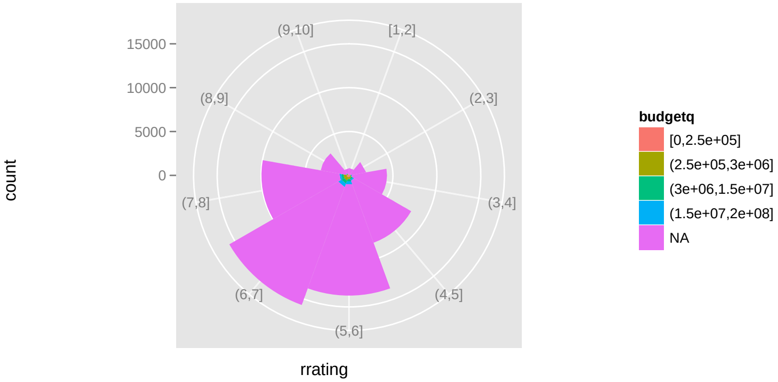
Line plot II



Polar plot I

```
# from ggplot2 docs
# Windrose + doughnut plot
movies$rrating <- cut_interval(movies$rating, length = 1)
movies$budgetq <- cut_number(movies$budget, 4)

doh <- ggplot(movies, aes(x = rrating, fill = budgetq))

# Wind rose
doh + geom_bar(width = 1) + coord_polar()
```

Polar plot II



Cons of Grammar of Graphics

- Grammar doesn't specify finer points of graphing such os font size or background color. GGplot2 Themes tries to mitigate this)
- Great for static graphs but not good for interactivity or animation. There are workarounds for this though.

Outline

Shiny

Shiny package from Rstudio

Shiny is a new package from RStudio that makes it incredibly easy to build interactive web applications with R.

Features

- Build useful web applications with only a few lines of codeno JavaScript required.
- Shiny user interfaces can be built entirely using R, or integrated with HTML, CSS, and JavaScript for more flexibility.
- Works in any R environment (Console R, Rgui for Windows or Mac, ESS, StatET, RStudio, etc.)

Features

- Pre-built output widgets for displaying plots, tables, and printed output of R objects.
- Fast bidirectional communication between the web browser and R using the websockets package.
- Uses a reactive programming model that eliminates messy event handling code, so you can focus on the code that really matters.

Architecture and Code Layout

- Shiny applications have two components - A user-interface definition script and server script
- It follows event-based programming model - Anytime any UI component is changed such as selection or movemnet of slider, an event is fired to the backend to handle.
- Server and client communicate seamlessly using websockets.
- An event triggers a server response and the UI is refreshed accordingly to reflect the change.

A live plot of mpg dataset

Outline

1. Introduction
2. Data Structures
3. Working with Data
4. Visualisation
5. Webapps
6. Integration with other Systems

Packages

- hadoop - RHadoop
- c++ - RCpp
- javascript - Shiny

Literate programming using Knitr

Literate programming

Literate programming is an approach to programming introduced by Donald Knuth in which a program is given as an explanation of the program logic in a natural language, such as English, interspersed with snippets of macros and traditional source code, from which a compilable source code can be generated

Knitr

- Transparent engine for dynamic report generation with R
- Implements literate programming paradigm
- Only one document to edit. Less pain to keep everything in sync
- Can output into different final outputs such as HTML, PDF etc

Knitr features

- Faithful output
- Built-in cache
- Easy Formatting
- Flexibility in output devices

Knitr Demo

Thank you

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- Email **vinayakh at gmail**