Introduction to Visualizations with R

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Tutorial Outline

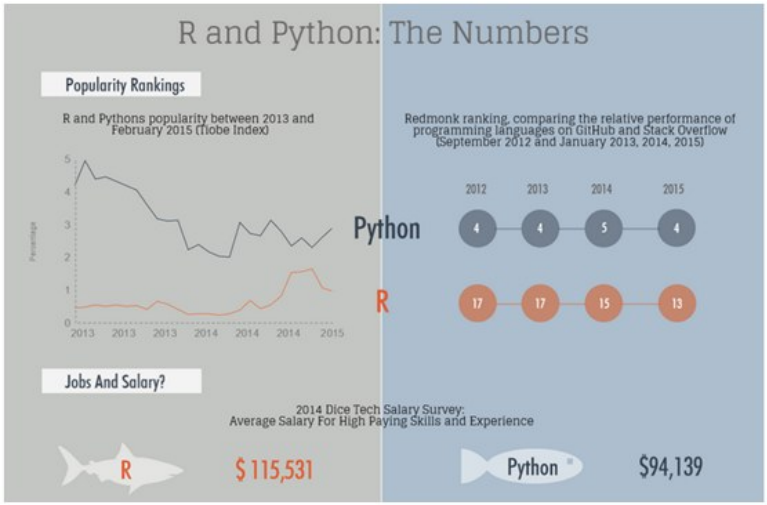
Preliminaries
Introduction to R
Visualizations
Working with R

Part I

Preliminaries

Motivation

- Derive and convey key insights from data
- Learn and use open source software
- Explore first/another programming language
- Gain ability to create insightful visualizations
- Be more marketable



[6]

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Why R?

- Absolutely free!
- Used in industry and academia.
- Has a great community:
  - StackOverflow
  - Blogs
  - Meetup groups
  - MOOCs
  - many, many others
- Has over 7900 packages available for use (for free!).
- Transparent code (e.g. easier to check for bugs).

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Why visualize?

- Capture uncertainty in the data
- Explore potential relationships/trends/missing patterns (or absence thereof)
- Convey key information

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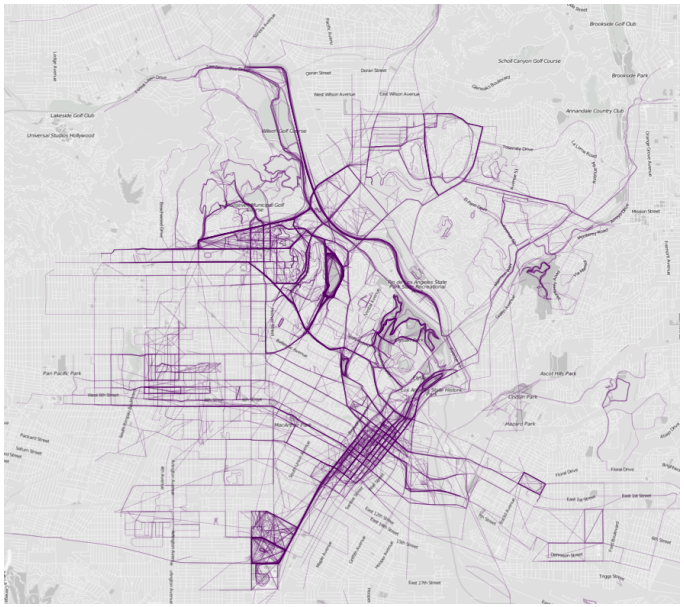
Tips for visualizations

- Know your audience
- *15 second rule:* if your audience won't be able to understand the graphic in 15 seconds, simplify
- Color and font choices
- Add text/labels to figure



[7]

Part II

Introduction to R

Overview of R per John Chambers [1]:

"To understand computations in R, two slogans are helpful:

- Everything that exists is an object.
- Everything that happens is a function call."

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Creating objects in R

Objects can be created in different ways, via:

- equal sign: `x = 3`
- left arrow: `y <- 2 * x + 1`
- right arrow: `10 -> z`

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Function by example

```
1   f <- function(x, y=1){
2           answer <- x * 2 + y + 1
3           return(answer)
4   }
5
6   f(2)          # 6
7   f(3, 2)       # 9
8   f(y=3, 2)     # 8
9   f(y=3, x=3)   # 10
```

Components of a function:

- Assign the function to a variable
- Add the 'function' keyword
- Specify any arguments (if any) that the function needs to compute the result
- Specify any argument defaults

Reading Data from File I

One approach is via `read.table()`. In the arguments of the function:

- `file:` specifies the (relative) location, file name and file extension
- `header:` if TRUE, tells R to include variables names when importing
- `sep:` tells R how the entires in the data set are separated
  - `sep=","`: when entries are separated by COMMAS
  - `sep="\t"`: when entries are separated by TAB
  - `sep=" "`: when entries are separated by SPACE

Reading Data from File II

```
filepath = "http://www.ats.ucla.edu/stat/data/test_missing_comma.txt"
### Other valid paths:
# filepath = "C:/Documents/test_missing_comma.txt"
# filepath = "./test_missing_comma.txt"
data <- read.table(
        file=filepath,
        header=TRUE,
        sep=","
        )
```

Working with Data Frames I

To check that a data set has been read-in correctly:

- View the complete data set by typing the variable name. (This is not recommended for large data sets.)

```
1 data
```

```
    prgtype gender  id ses schtyp level
1   general      0  70   4      1     1
2    vocati      1 121   4     NA     1
3   general      0  86  NA     NA     1
4    vocati      0 141   4      3     1
5  academic      0 172   4      2     1
6  academic      0 113   4      2     1
7   general      0  50   3      2     1
8  academic      0  11   1      2     1
```

Working with Data Frames II

- View the first 5 lines of the dataset via `head()`:

```
1  head(data, 5)
```

```
    prgtype gender  id ses schtyp level
1   general      0  70   4      1     1
2    vocati      1 121   4     NA     1
3   general      0  86  NA     NA     1
4    vocati      0 141   4      3     1
5  academic      0 172   4      2     1
```

Working with Data Frames III

- View the last 7 lines of the dataset via `tail()`:

```
1 tail(data, 7)
```

	prgtype	gender	id	ses	schtyp	level
2	vocati	1	121	4	NA	1
3	general	0	86	NA	NA	1
4	vocati	0	141	4	3	1
5	academic	0	172	4	2	1
6	academic	0	113	4	2	1
7	general	0	50	3	2	1
8	academic	0	11	1	2	1

Working with Data Frames IV

- Check the variable names via `names()`:

```
1  names(data)
```

```
[1] "prgtype" "gender"  "id"      "ses"     "schtyp"  "level"
```

- Check the size of the data set via `dim()`:

```
1  dim(data)
```

```
[1] 8 6
```

- See the first 3 entries for variable 'gender' via `head()`:

```
1  head(data$gender)
```

```
[1] 0 1 0 0 0 0
```

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Working with Data Frames V

- Verify ranges and check for missing data via `summary()`:

```
1  summary(data)
```

```
   prgtype      gender          id             ses          schtyp      level
 vocati:2   Min.   :0.000   Min.   : 11.0   Min.   :1.000   Min.   :1   Min.   :1
general:3   1st Qu.:0.000   1st Qu.: 65.0   1st Qu.:3.500   1st Qu.:2   1st Qu.:1
academic:3  Median :0.000   Median : 99.5   Median :4.000   Median :2   Median :1
            Mean   :0.125   Mean   : 95.5   Mean   :3.429   Mean   :2   Mean   :1
            3rd Qu.:0.000   3rd Qu.:126.0   3rd Qu.:4.000   3rd Qu.:2   3rd Qu.:1
            Max.   :1.000   Max.   :172.0   Max.   :4.000   Max.   :3   Max.   :1
                                            NA's   :1       NA's   :2
```

Adding Functionality to Base R

- Base R is what you download off CRAN `www.cran.r-project.org`
- Available packages are listed here: `https://cran.r-project.org/web/packages/`
- Install an R package(s) via `install.packages()`:

```
1 install.packages("ggplot2")
```

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Part III

Visualizations

Data Set for Tutorial I

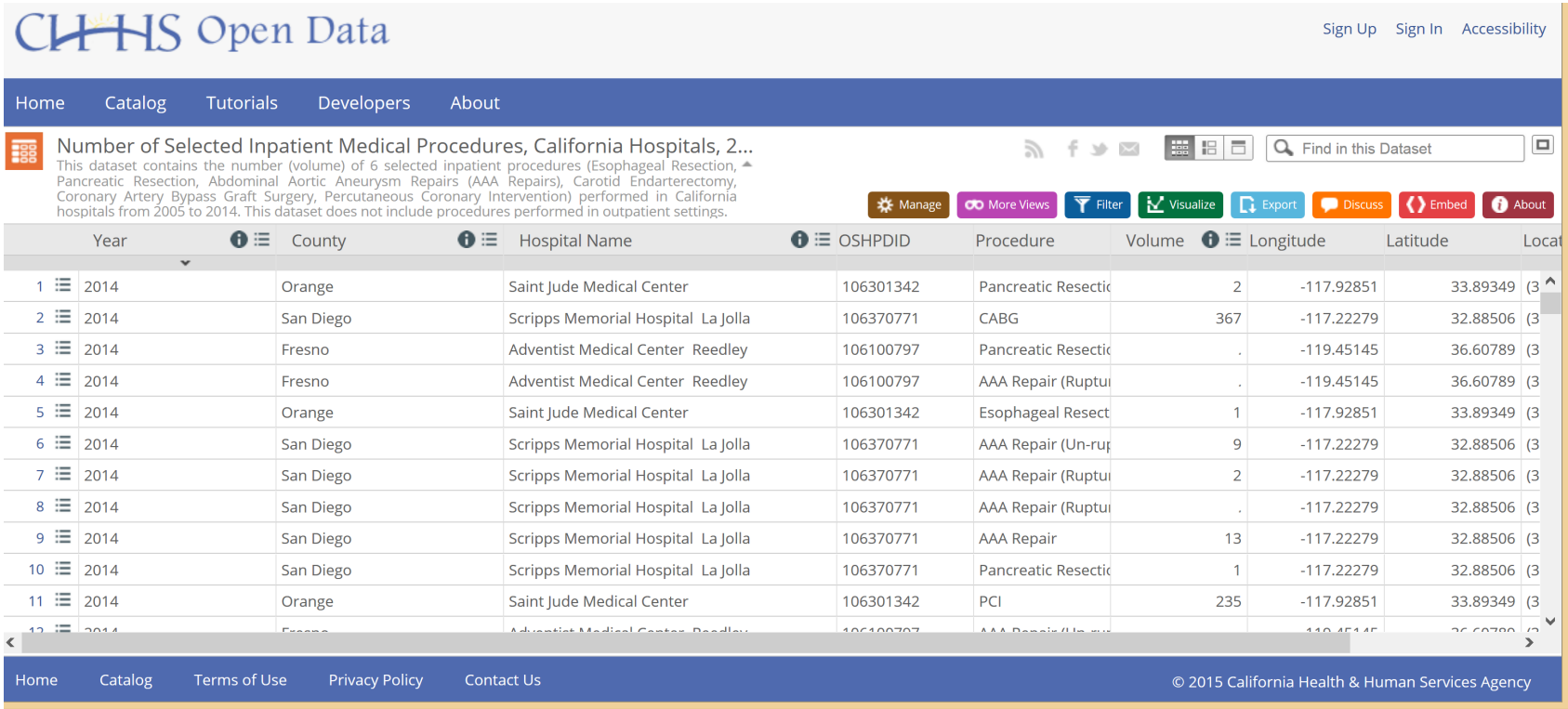
Data set for this tutorial comes from State of California. Please download it from

`https://chhs.data.ca.gov/Healthcare/Number-of-Selected-Inpatient-Medical-Procedures-Ca/mdt8-gwyw`

To read it into R, type:

```
1  data <- read.csv(
2    file = "Number_of_Selected_Inpatient_Medical
         _Procedures__California_Hospitals__2005-2014.
         csv",
3    stringsAsFactors = FALSE
4    )
```

Data Set for Tutorial II



CHHS Open Data

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Number of Selected Inpatient Medical Procedures, California Hospitals, 2...

This dataset contains the number (volume) of 6 selected inpatient procedures (Esophageal Resection, Pancreatic Resection, Abdominal Aortic Aneurysm Repairs (AAA Repairs), Carotid Endarterectomy, Coronary Artery Bypass Graft Surgery, Percutaneous Coronary Intervention) performed in California hospitals from 2005 to 2014. This dataset does not include procedures performed in outpatient settings.

Find in this Dataset

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	Year	County	Hospital Name	OSHPDID	Procedure	Volume	Longitude	Latitude	Locat
1	2014	Orange	Saint Jude Medical Center	106301342	Pancreatic Resectic	2	-117.92851	33.89349	(3
2	2014	San Diego	Scripps Memorial Hospital La Jolla	106370771	CABG	367	-117.22279	32.88506	(3
3	2014	Fresno	Adventist Medical Center Reedley	106100797	Pancreatic Resectic	.	-119.45145	36.60789	(3
4	2014	Fresno	Adventist Medical Center Reedley	106100797	AAA Repair (Ruptu	.	-119.45145	36.60789	(3
5	2014	Orange	Saint Jude Medical Center	106301342	Esophageal Resect	1	-117.92851	33.89349	(3
6	2014	San Diego	Scripps Memorial Hospital La Jolla	106370771	AAA Repair (Un-rup	9	-117.22279	32.88506	(3
7	2014	San Diego	Scripps Memorial Hospital La Jolla	106370771	AAA Repair (Ruptu	2	-117.22279	32.88506	(3
8	2014	San Diego	Scripps Memorial Hospital La Jolla	106370771	AAA Repair (Ruptu	.	-117.22279	32.88506	(3
9	2014	San Diego	Scripps Memorial Hospital La Jolla	106370771	AAA Repair	13	-117.22279	32.88506	(3
10	2014	San Diego	Scripps Memorial Hospital La Jolla	106370771	Pancreatic Resectic	1	-117.22279	32.88506	(3
11	2014	Orange	Saint Jude Medical Center	106301342	PCI	235	-117.92851	33.89349	(3

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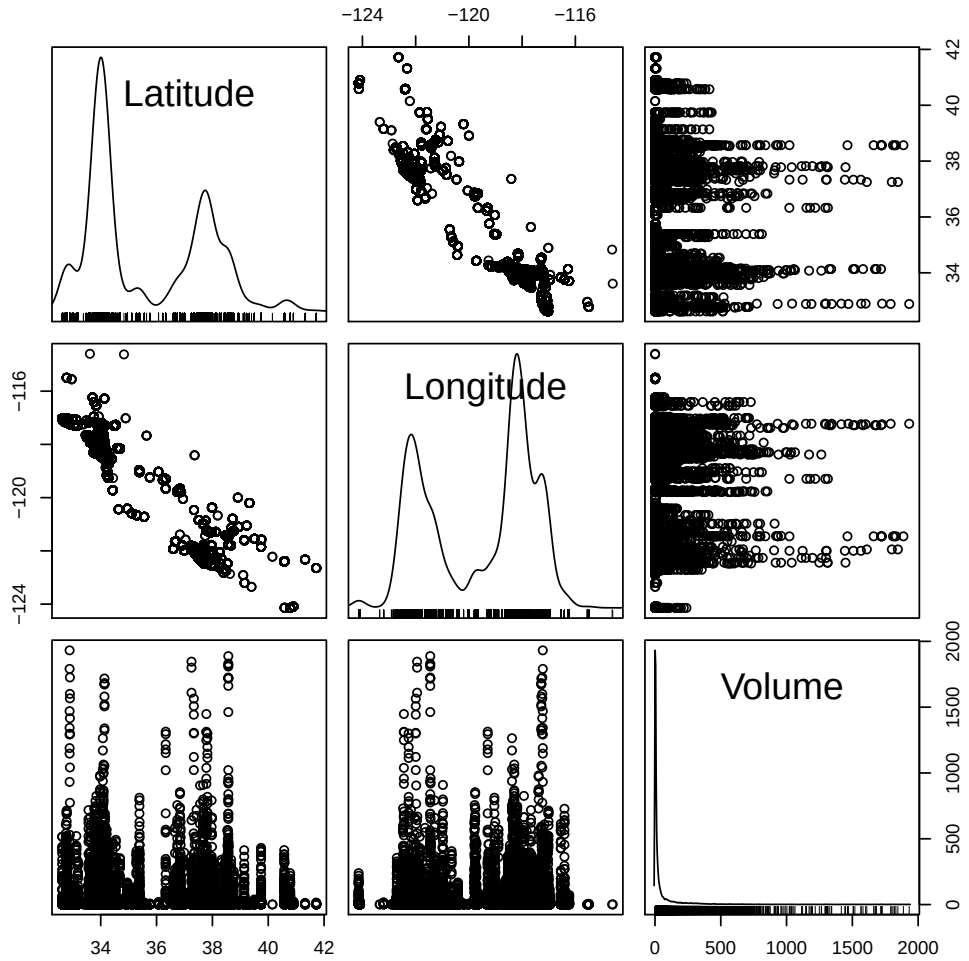
Scatterplot (v0.1) I

To get a quick peak into the numerical variables in the data `scatterplotMatrix()`:

```
1 # Load package 'car' to use scatterplotMatrix():
2 library(car)
3 scatterplotMatrix(
4     x = data[, c("Latitude", "Longitude", "Volume")],
5     smoother = FALSE,
6     reg.line = FALSE
7     )
```

Scatterplot (v0.1) II



Scatterplot (v0.2) I

To get a quick peak into the numerical variables and the trends in the data, modify arguments of `scatterplotMatrix()`:

```
1  ?scatterplotMatrix # for documentation
2  library(car)
3  scatterplotMatrix(
4    x = data[, c("Latitude", "Longitude", "Volume")],
5    reg.line = FALSE
6    )
```

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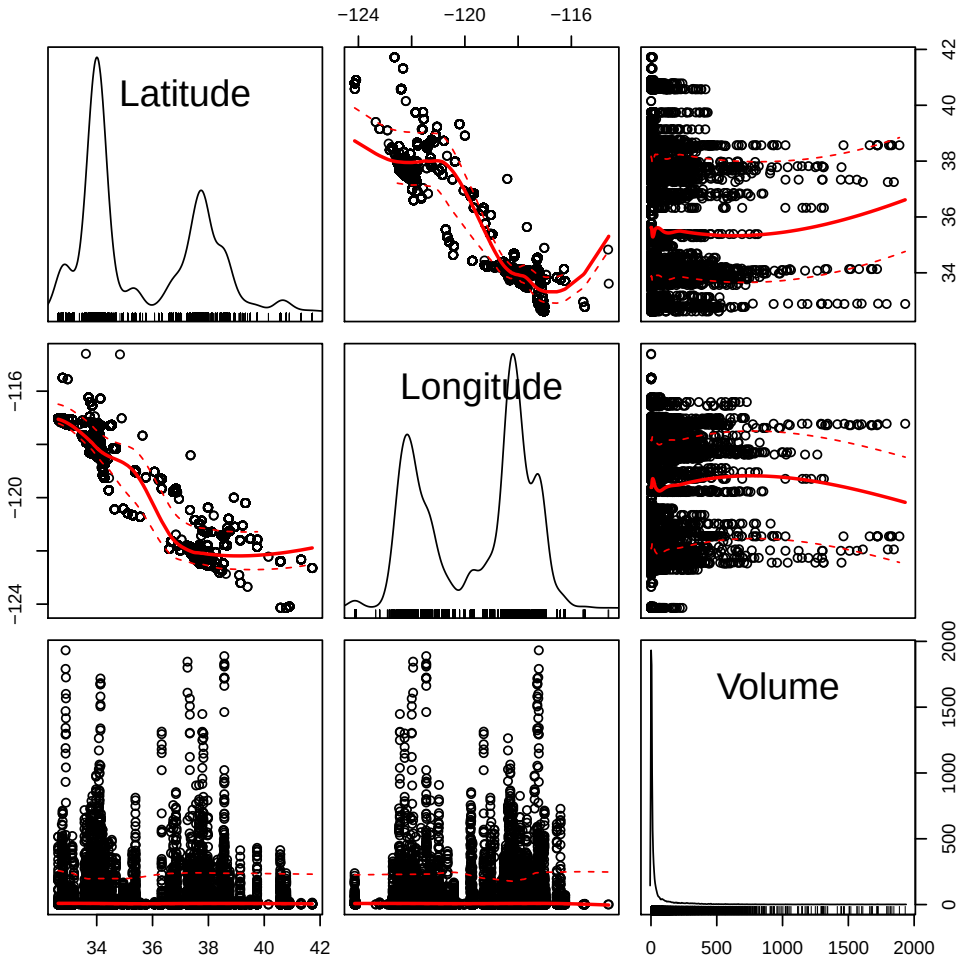
Scatterplot (v0.2) II



Scatterplot (v0.3) I

To improve the color scheme, modify arguments of `scatterplotMatrix()`.

```
library(car)
scatterplotMatrix(
  x = data[, c("Latitude", "Longitude", "Volume")],
  reg.line = FALSE,
  col=c(3,
    "orangered",
    rgb(176/256, 196/256, 222/256, alpha=0.5)
    ),
  pch=19,
  lwd=3
  )
```

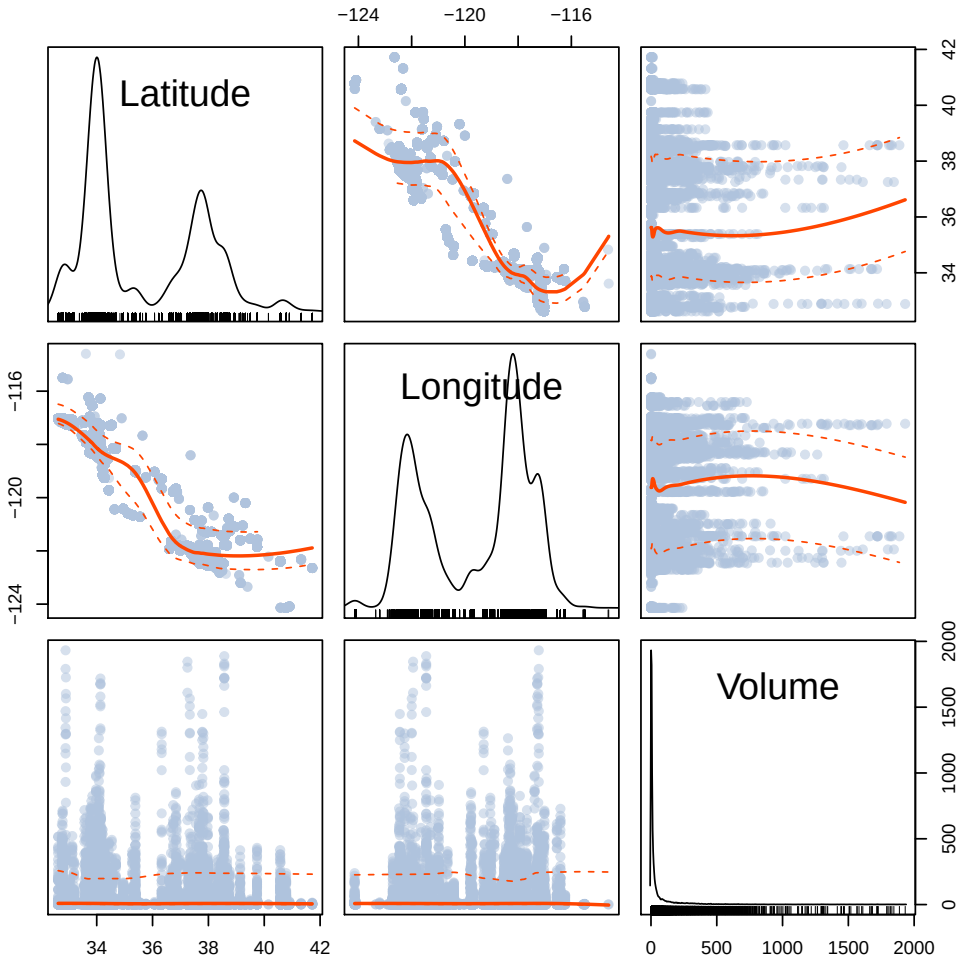
Scatterplot (v0.3) II

You can specify a color in R via:

- Number (e.g. 1 = black, 2 = red, etc.)
- Name (e.g. "black", "red", "dodgerblue")
- RGB (e.g. c(0,0,0) = black, c(1,0,0) = red, etc.)
- Please see `http://research.stowers-institute.org/efg/R/Color/Chart/` for color references.

Note the order of color arguments.

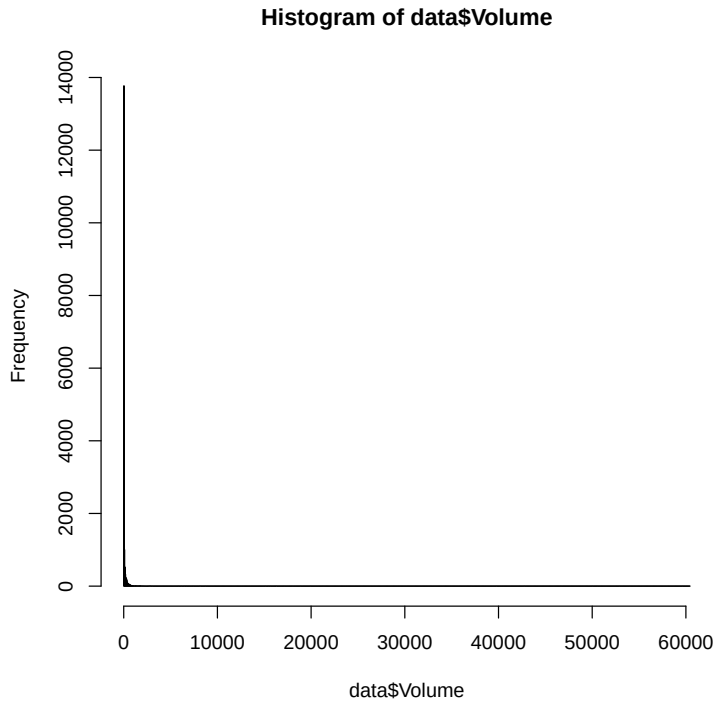
Scatterplot (v0.3) III



Histogram I

To see the distribution of one variable, use `hist()`:

```
1 hist(
2    data$Volume,
3    breaks=1000
4    )
5 # Is anything 'off'?
```



Histogram II

Let's examine the potential outlier:

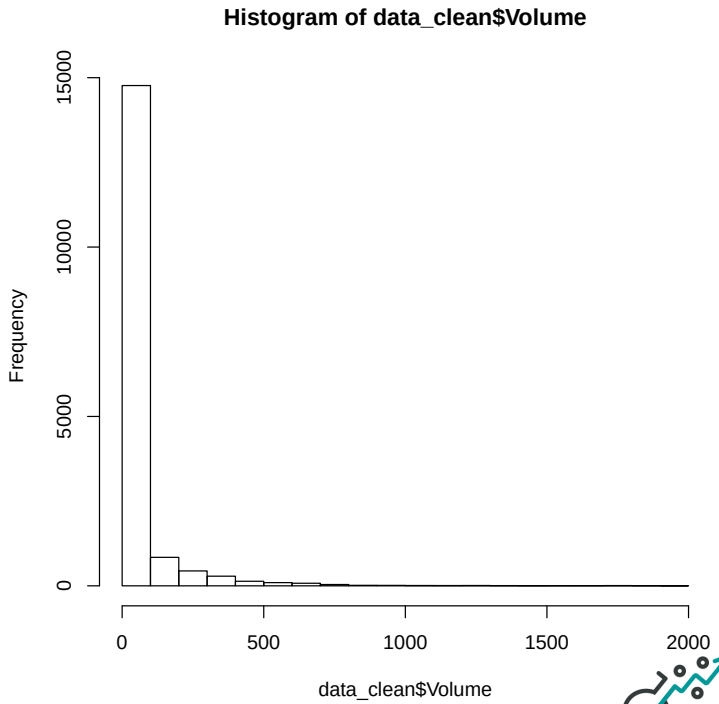
```
1  subset(
2     x = data,
3     Volume == max(Volume, na.rm=TRUE)
4     )
```

```
      ..Year    County Hospital.Name OSHPDID Procedure Volume Longitude Latitude Location
41783    2005 STATEWIDE     STATEWIDE      NA       PCI  60418        NA       NA
```

Histogram III

Entry seems to be an aggregate number, not county/year level. To remove the outlier:

```
1  data_clean = subset(
2     x = data,
3     County != "STATEWIDE"
4     )
5  hist(data_clean$Volume)
6  # Is anything 'off' now?
       (Exercise.)
```



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'Nicer' Histogram I

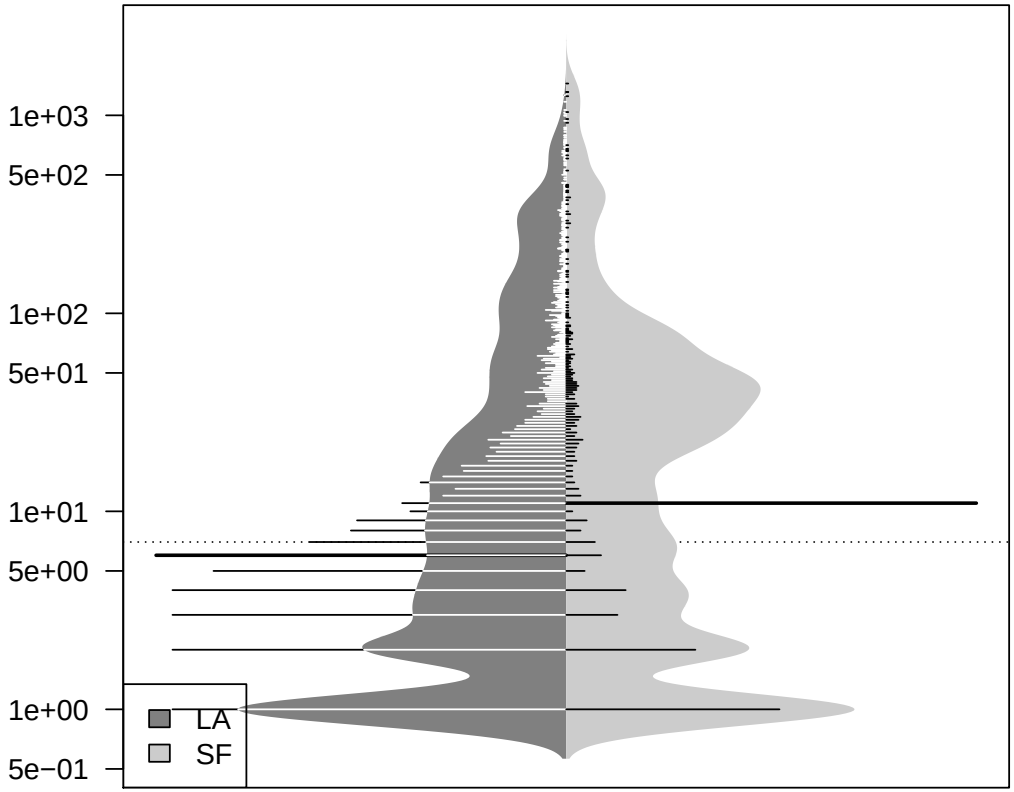
To compare two variables side-by-side, use `beanplot()`:

```
1  library(beanplot)
2  # Subset the data to LA and SF:
3  data_LA_SF <- subset(
4     x = data_clean,
5     County %in% c("Los Angeles", "San Francisco")
6     )
7
8  # Orient y-axis labels to be more readable:
9  op <- par(las=2)
10 beanplot(
11    Volume ~ as.factor(County),
12    data = data_LA_SF,
13    xlab = "",
14    log = "y",
```

'Nicer' Histogram II

```
15      side = "both",
16      col = list( c( grey(0.5), "white"), grey(0.8) ),
17      border = NA,
18      overallline = "median",
19      ll = 0.005,
20      show.names=FALSE
21      )
22
23
24  legend(
25      x = "bottomleft",
26      fill=c( grey(0.5), grey(0.8) ),
27      legend=c( "LA", "SF" )
28      )
29  par(op)
```

'Nicer' Histogram III



Exercise I

In the healthcare data set, after we removed statewide patient admissions, is the largest volume of patients now seen at a Californian hospital a potential outlier? How do you know?

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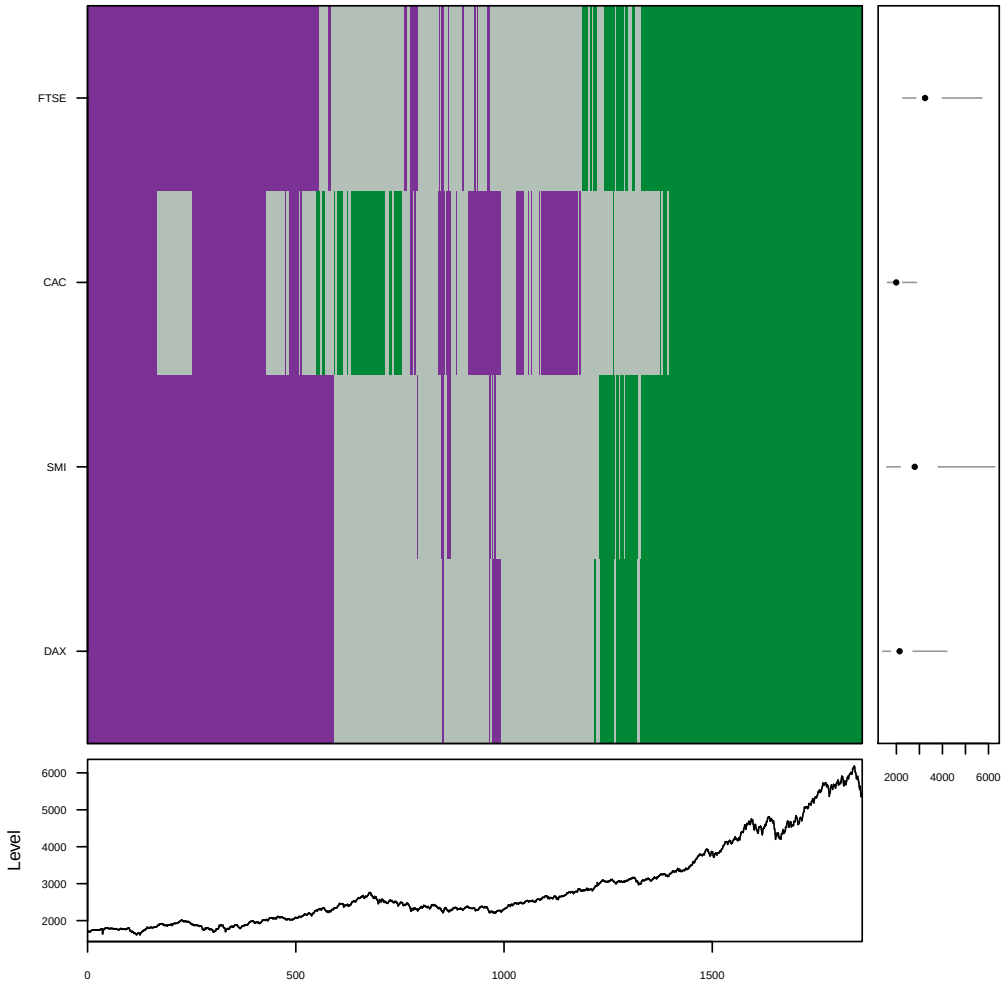
Multivariate Time Series Plots (v0.1) I

To plot more than variables one at a time, use `mvtsplot()`[5]:

```
1 library(mvtsplot)
2 # Data = Daily Closing of Stock Indices:
3 data(EuStockMarkets)
4 # Purple=low, grey=medium,
5 # green=high, white=missing values:
6 mvtsplot(EuStockMarkets)
```

Multivariate Time Series Plots (v0.1) II

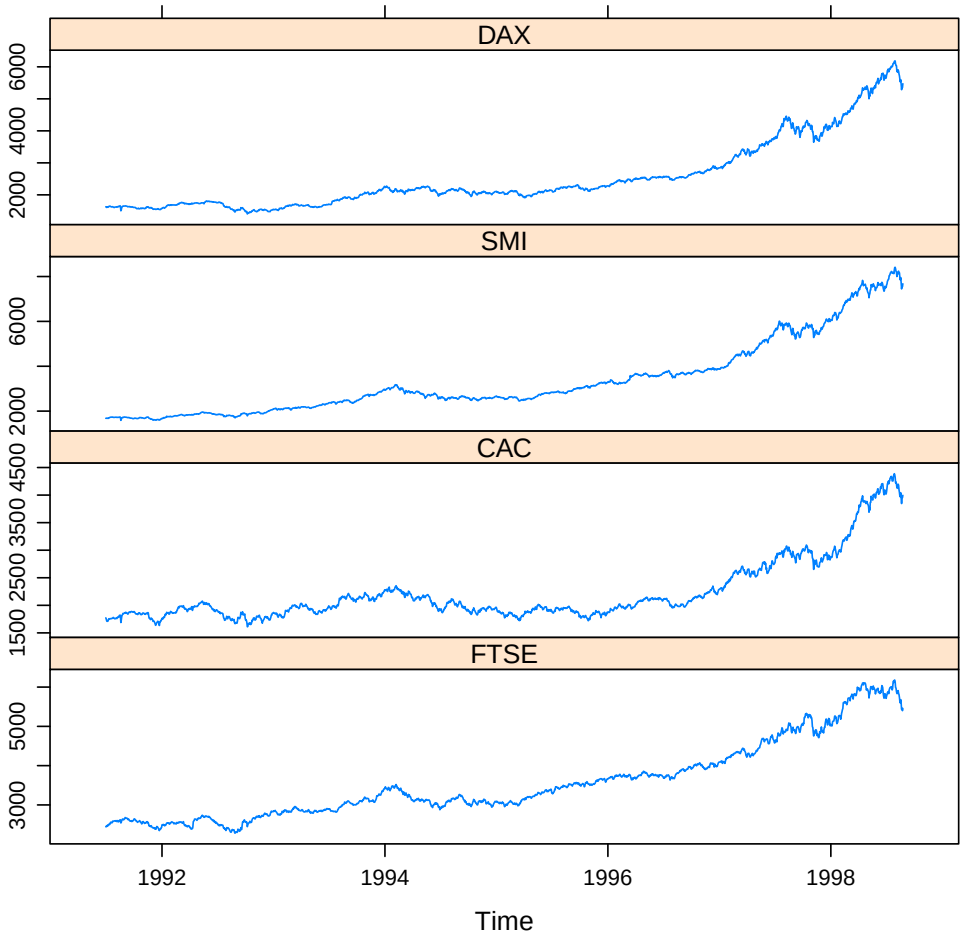


Multivariate Time Series Plots (v0.2) I

Another way to plot more than one variable at a time, is via `xyplot()`:

```
1 library(lattice)
2 data(EuStockMarkets)
3 xyplot(EuStockMarkets)
```

Multivariate Time Series Plots (v0.2) II



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Multivariate Time Series Plots (v0.3) I

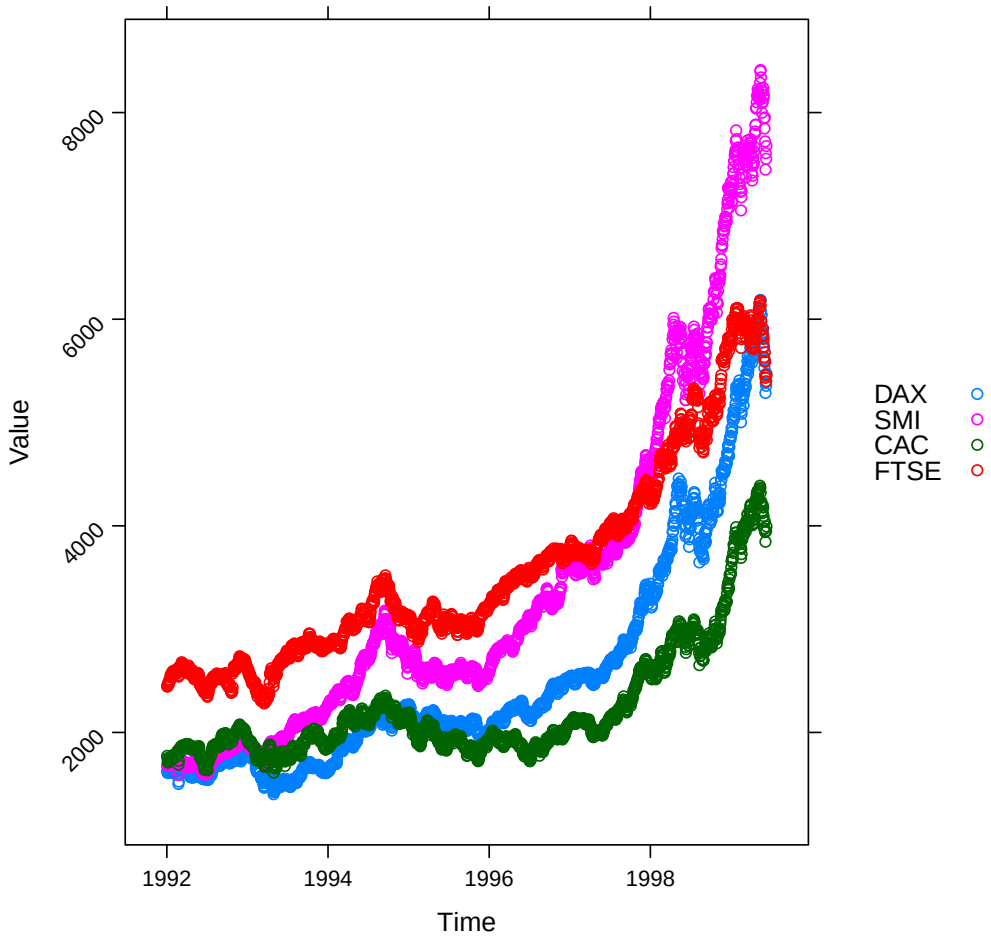
To customize the output, modify controls of `xyplot()`:

```
1  library(lattice)
2  library(reshape2)
3  data(EuStockMarkets)
4  # Stack data per [2]:
5  df = cbind.data.frame(
6     "id"=1:nrow(EuStockMarkets),
7     EuStockMarkets
8     )
9  df_stacked = melt(
10    df,
11    id="id"
12    )
13 # Adding labels per [3]:
```

Multivariate Time Series Plots (v0.3) II

```
14  xyplot( df_stacked$value ~ df_stacked$id,
15    groups=df_stacked$variable,
16    auto.key = list(space = "right"),
17    scales = list(y = list(rot = 45),
18                  x = list(
19                    at=c(0,500, 1000, 1500),
20                    labels=seq(from=1992, to=1998,
                                 by=2)
21                    )
22                  ),
23    xlab="Time",
24    ylab="Value"
25    )
```

Multivariate Time Series Plots (v0.3) III



Multivariate Time Series Plots (v0.4) I

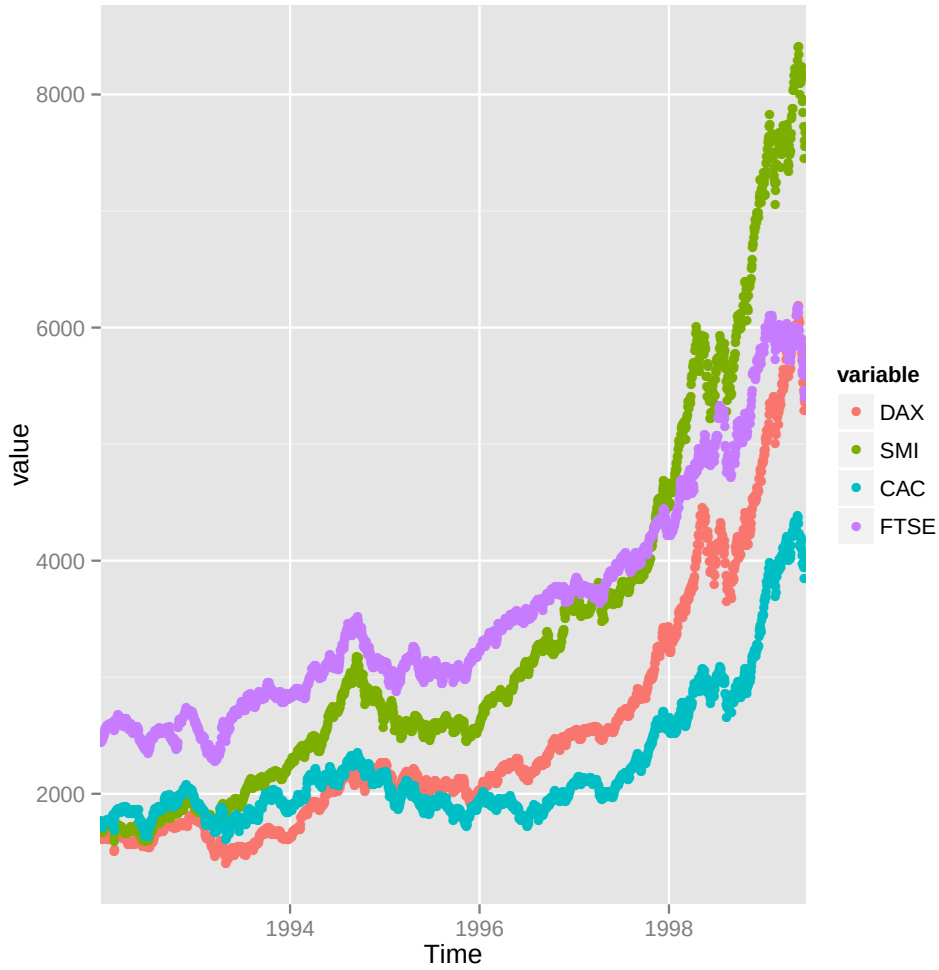
Another way to plot more than one variable at a time, is via ggplot():

```
1  library(ggplot2)
2  library(reshape2)
3  data(EuStockMarkets)
4  df = cbind.data.frame(
5     "id"=1:nrow(EuStockMarkets),
6     EuStockMarkets
7     )
8  df_stacked = melt(
9     df,
10    id="id"
11    )
12 # Ading labels per [4]:
```

Multivariate Time Series Plots (v0.4) II

```
13  ggplot(
14    data = df_stacked,
15    aes(x = id, y = value, color = variable)
16    ) +
17    geom_point() +
18    scale_x_discrete(name="Time",
19      breaks=seq(from=0, to=1500, by=500),
20      labels=seq(from=1992, to=1998, by=2)
21      )
```

Multivariate Time Series Plots (v0.4) III



Multivariate Time Series Plots (v0.5) I

Exercise II

Analyze the approval ratings of the President of the United States in the data set`presidents`. What stands out and why?

Hints:

- Load the data set `presidents`.
- Convert the data set to be in matrix format, one row per year.
- Plot the data set.
- Examine the result.

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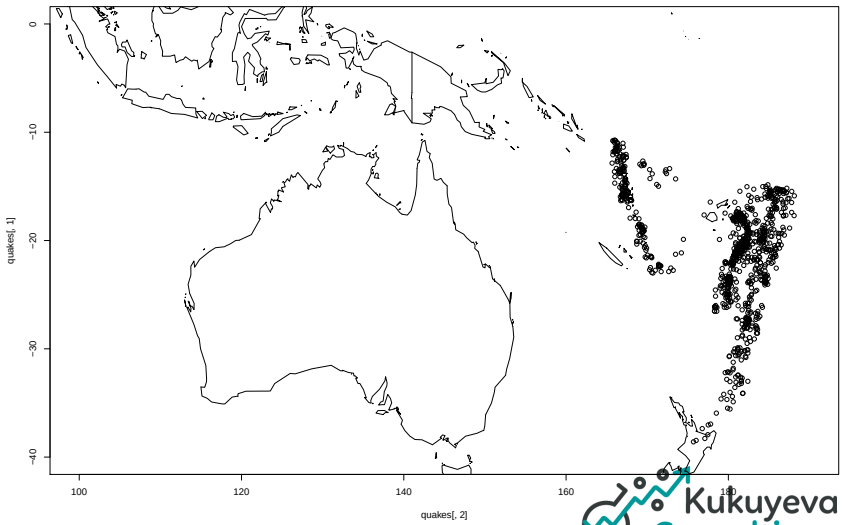
Geographic Maps

Map of Fiji Earthquakes Since 1964

To overlay a map to a plot containing latitude and longitude, load the package `maps`:

```
1  data(quakes)
2  library(maps)
3  plot(
4            quakes$long,
5            quakes$lat,
6            xlim=c(100, 190),
7            ylim=c(-40, 0)
8            )
9  map("world", add=TRUE)
```



Geographic Maps I

Map of Fiji Earthquakes Since 1964

To include information on magnitude of earthquake, use `cex` argument of the `plot()` function:

```
# Step 1: Recode magnitude to have 3
    categories only
ind<-which(quakes$mag<5)
ind2<-which(quakes$mag<6 & quakes$mag >=5)
ind3<-which(quakes$mag>=6)
color<-rep(NA, length(quakes$mag))
color[ind]<-1; color[ind2]<-2; color[ind3]<-3


```

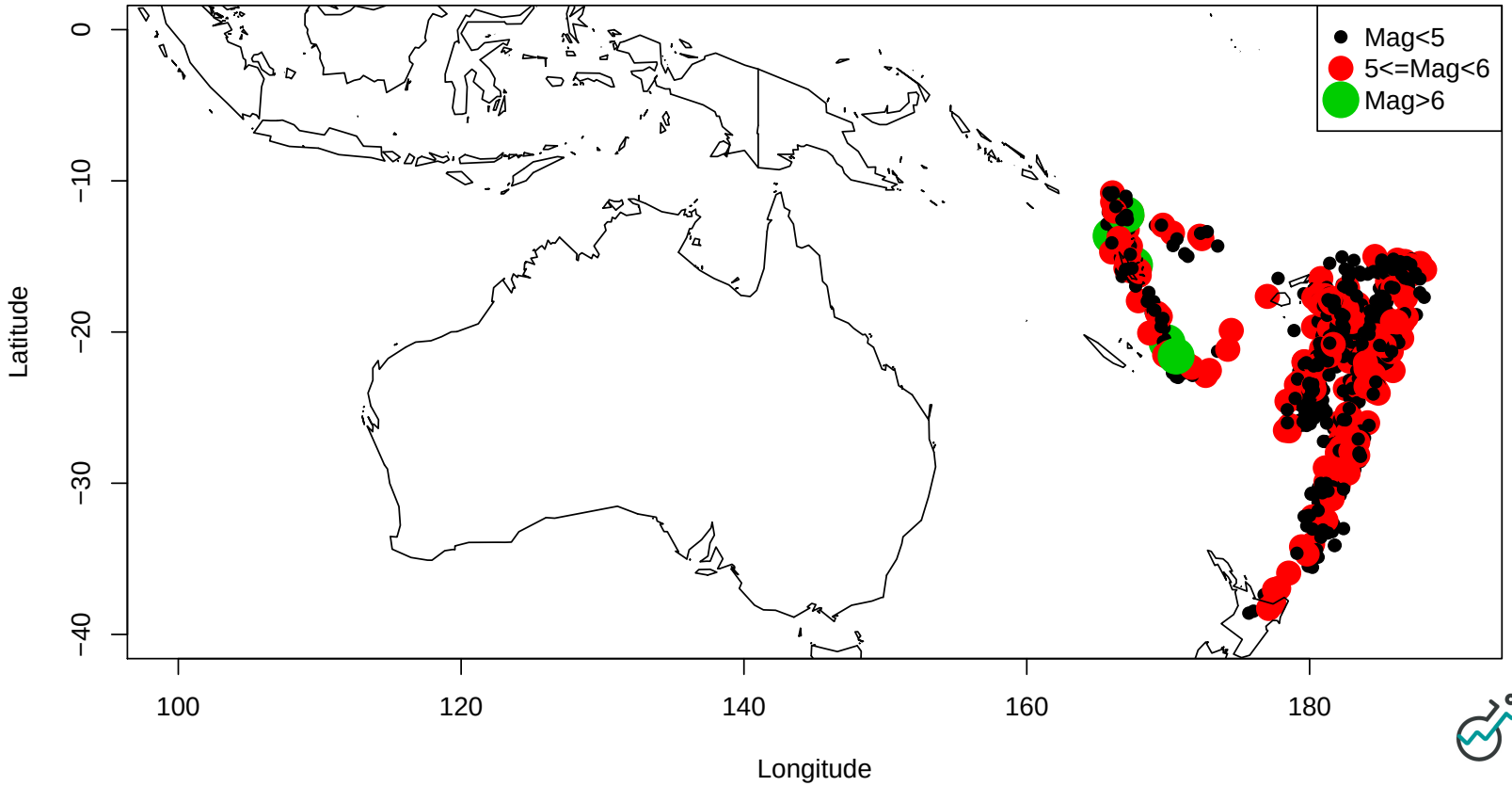
Geographic Maps II

Map of Fiji Earthquakes Since 1964

```
11 # Step 2: Plot
12 plot(quakes$long, quakes$lat, cex=color, pch
       =19, col=color, xlim=c(100, 190), ylim=
       c(-40,0), xlab="Longitude", ylab="Latitude
       ")
13 legend("topright", pch=19, col=1:3, c("Mag<5",
        "5<=Mag<6", "Mag>6"), pt.cex=1:3)
14 map("world", add=TRUE)
```

Geographic Maps III

Map of Fiji Earthquakes Since 1964



Projection Maps I

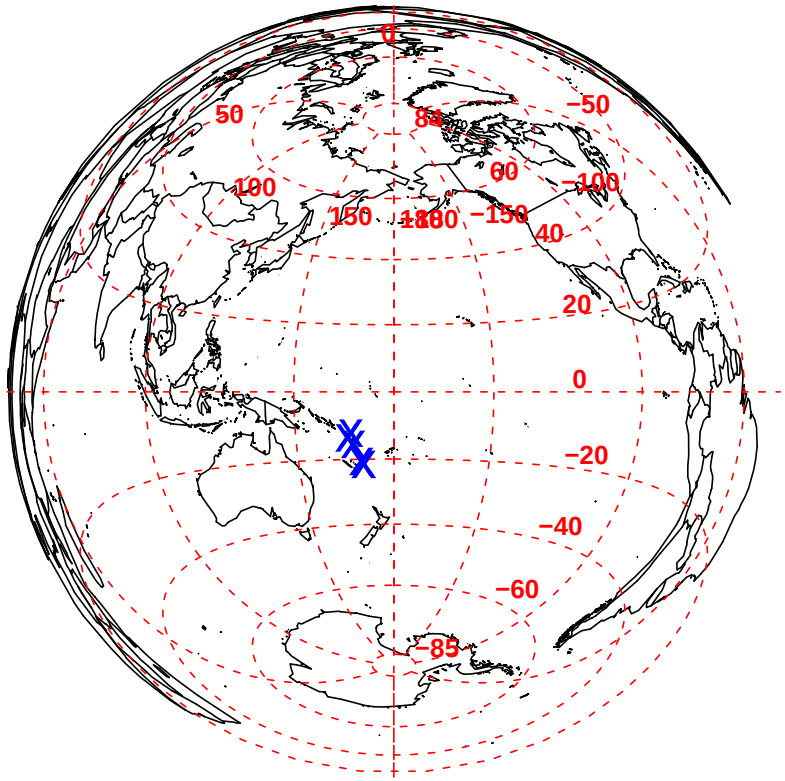
Map of Fiji Earthquakes Since 1964

For a different perspective of a map, use `mapproject()`:

```
1  library(mapproj)
2  library(maps)
3  m <- map('world',plot=FALSE)
4  # Projection is Azimuthal with equal-area
5  map('world',proj='azequalarea',orient=c(
       longitude=0,latitude=180,rotation=0))
6  map.grid(m,col=2)
7  points(mapproject(list(
       y=quakes$lat[which(quakes$mag>=6)],
       x=quakes$long[which(quakes$mag>=6)])),
       col="blue",pch="x",cex=2)
```

Projection Maps II

Map of Fiji Earthquakes Since 1964



Exercise III

For the ozone data set [1], determine the region of the world that the observations correspond to and overlay the appropriate map.

[1] http://www.ats.ucla.edu/stat/R/faq/ozone.csv

Part IV

Working with R

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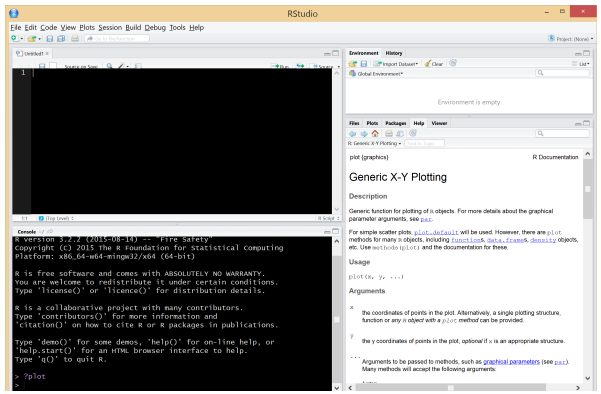
Installing R and RStudio

R: Go to `http://cran.r-project.org/`, select your operating system and download the latest version: 3.2.3 (Release 2015/12/10).

RStudio: Go to `https://www.rstudio.com/products/rstudio/download/`, select your operating system and download the installer (if available).



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Package Installation

To install a package in R, use `install.packages()`:

```
1  install.packages("lattice")
2  install.packages("ggplot2")
3  # OR
4  install.packages( c("lattice", "ggplot2") )
```

Saving Plots as a PDF

For Static Plots

Note: The files will be saved in the folder specified with `setwd()`.
To save a static plot in `R` as a PDF, use function `pdf()`:

```
1 # To save the image to the desktop:
2 setwd("~/Desktop")
3 pdf("filename.pdf")
4 wireframe(volcano, col.regions = terrain.
      colors(100), asp = 1, color.key=TRUE,
      drape=TRUE, scales = list(arrows = FALSE))
5 dev.off()
```

Saving Plots as a PDF

For Dynamic Plots

Note: The files will be saved in the folder specified with `setwd()`. To save a dynamic plot in `R` as a PDF, use function `rgl.snapshot()`:

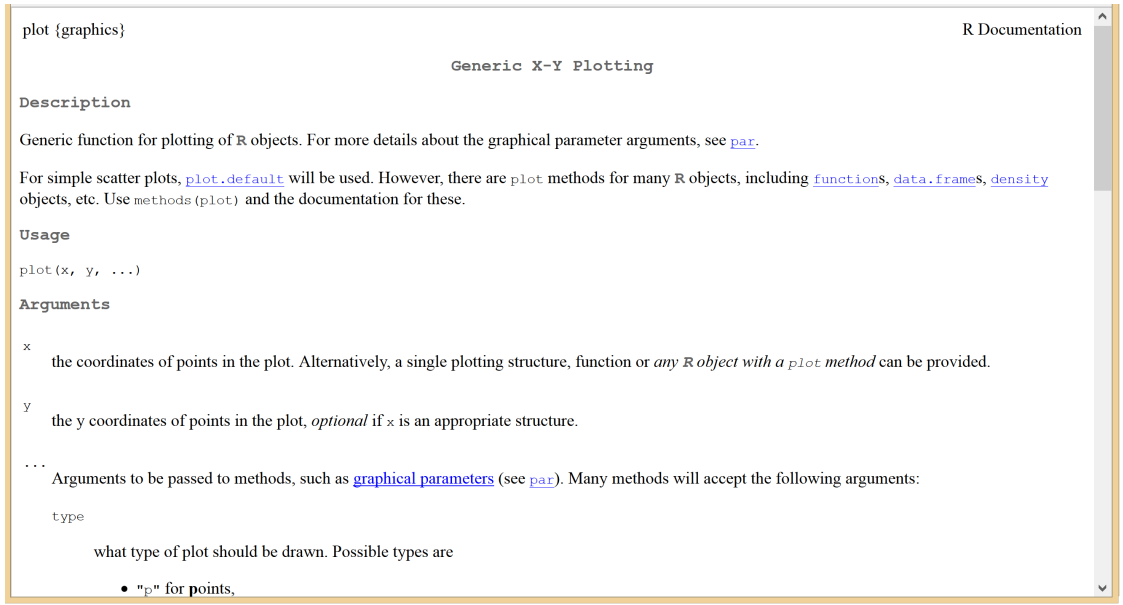
```
# To save the image to the desktop:
setwd("~/Desktop")
# Step 1: Produce the 3D image:
plot3d(x=quakes$long, y=quakes$lat, z=quakes
    $depth, xlab="Longitude", ylab="Latitude",
     zlab="Depth")
# Step 2: Can rotate before taking a snapshot:
rgl.snapshot("quakes.png")
```

Most Common Error Messages

R Help: Approach 1

For help with any function in R, put a question mark before the function name to determine what arguments to use, examples and background information.

```
1  ?plot
```



plot {graphics} R Documentation

Generic X-Y Plotting

Description

Generic function for plotting of R objects. For more details about the graphical parameter arguments, see par.

For simple scatter plots, plot.default will be used. However, there are plot methods for many R objects, including functions, data.frames, density objects, etc. Use methods(plot) and the documentation for these.

Usage

```
plot(x, y, ...)
```

Arguments

x — the coordinates of points in the plot. Alternatively, a single plotting structure, function or *any R object with a plot method* can be provided.

y — the y coordinates of points in the plot, *optional* if x is an appropriate structure.

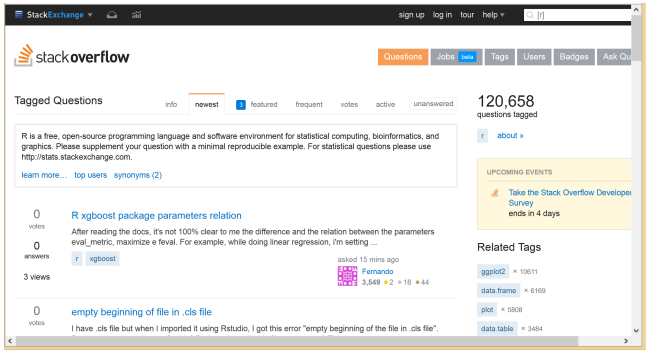
... — Arguments to be passed to methods, such as graphical parameters (see par). Many methods will accept the following arguments:

type — what type of plot should be drawn. Possible types are

- "p" for points,

R Help: Approaches 2 and 3

- For help with any function in R, search answers on StackOverflow (SO).
- For help with any function in R, when all else fails, ask a question on StackOverflow. Don't forget to follow the SO tips: `http://stackoverflow.com/help/how-to-ask`



Online Resources for R I

Download R: *http://cran.stat.ucla.edu/*

Download RStudio: *https://www.rstudio.com/*

R Reference Card:
http://cran.r-project.org/doc/contrib/Short-refcard.pdf

R Graphics Gallery:
http://research.stowers-institute.org/efg/R/

R Graph Gallery: *http://addictedtor.free.fr/graphiques/*

More R tutorials:

IK: *http://www.KukuyevaConsulting.com/tutorials*

UCLA IDRE: *http://www.ats.ucla.edu/stat/r/*

Online Resources for R II

UCLA SCC: *http://scc.stat.ucla.edu/mini-courses/*

JSS:

Stackoverflow:

Blogs:

1. http://adv-r.had.co.nz/
2. http://www.sixhat.net/how-to-plot-multpile-data-series-with-ggplot.html
3. http://stackoverflow.com/questions/17584248/exact-axis-ticks-and-labels-in-r-lattice-xyplot
4. https://rstudio-pubs-static.s3.amazonaws.com/3364_d1a578f521174152b46b19d0c83cbe7e.html
5. www.jstatsoft.org/v25/c01/paper
6. http://www.kdnuggets.com/2015/05/r-vs-python-data-science.html
7. http://flowingdata.com/2014/02/05/where-people-run/
8. https://www.facebook.com/notes/facebook-engineering/visualizing-friendships/469716398919

Thank you.
Any questions?