MFE R Programming Workshop

Week 4

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Introduction

Questions

Any questions before we start?

Overview of Week 4

- Strings
- Dates
- Plotting with Dates
- Time-Series Data in `R` (`xts`)
- Plotting in `R`
- Lab

Strings

Strings

- A string is a sequence of characters.
- In R, a string falls in the character class.

```
mystring <- "Hello"
str(mystring)
```

```
##  chr "Hello"
```

- Character vectors are created like numeric vectors.

```
myvec <- c("Hello", "Goodbye")
str(myvec)
```

```
##  chr [1:2] "Hello" "Goodbye"
```

Manipulating Strings

- `R` provides many functions to manipulate strings.
  - `grep()`: Searches for a substring, like the Linux command of the same name.
  - `gsub()`: Replaces all matches of a substring with another string.
  - `nchar()`: Finds the length of a string.
  - `paste()` and `paste0()`: Assembles a string from parts.
  - `sprintf()`: Returns a character vector containing a formatted combination of text and variable values.
  - `substr()`: Extracts a substring.
  - `strsplit()`: Splits a string into substrings.
- Hadley Wickham's `stringr` package provides additional functions for using regular expressions and examining text data. See more here.

grep()

- The call grep(pattern, x) searches for a specified substring pattern in a vector x of strings.
- If x has n elements—that is, it contains n strings—then grep(pattern, x) will return a vector of length up to n.
- Each element of this vector will be the index in x at which a match of pattern as a substring of x was found.

```r
grep("Pole",c("Equator","North Pole","South Pole"))
```

```
## [1] 2 3
```

gsub()

- The call gsub(pattern, replacement, x) searches for a specified substring pattern in a vector x of strings and replaces it with the provided replacement string.
- If x has n elements, gsub() will return a string vector of length to n.
- If the substring is not found, it returns the original string.

```
gsub(" Pole","",c("Equator","North Pole","South Pole"))
```

```
## [1] "Equator" "North"   "South"
```

nchar()

- The call `nchar(x)` finds the length of a string `x`.

```
nchar("South Pole")
```

```
## [1] 10
```

paste()

- The call `paste(...)` concatenates several strings, returning the result in one long string.

```
paste("North","and","South","Poles")
```

```
## [1] "North and South Poles"
```

```
paste("North","Pole",sep="")
```

```
## [1] "NorthPole"
```

```
# paste0 is same as sep="" (more efficient)
paste0("North","Pole") == paste("North","Pole",sep="")
```

```
## [1] TRUE
```

`sprintf()`

- The call `sprintf(...)` assembles a string from parts in a formatted manner.
- Similar to the `C` function `printf`.

```
i <- 8
sprintf("the square of %d is %d",i,i^2)
```

```
## [1] "the square of 8 is 64"
```

substr()

- The call substr(x,start,stop) returns the substring in the given character position range start:stop in the given string x.

```r
substr("Equator",start = 3,stop = 5)
```

```
## [1] "uat"
```

strsplit()

- The call strsplit(x,split) splits a string x into a list of substrings based on another string split in x.

```
strsplit("10-05-2017",split="-")
```

```
## [[1]]
## [1] "10"   "05"   "2017"
```

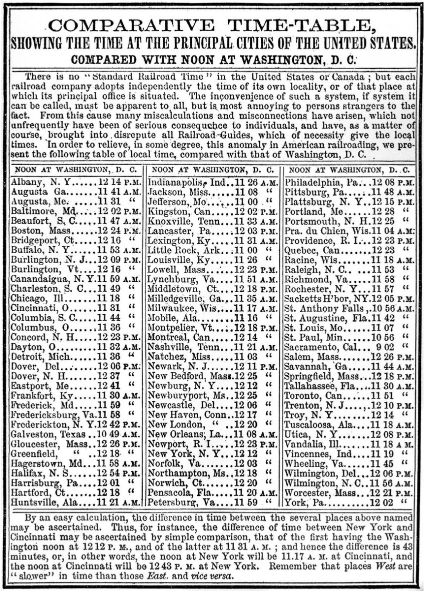
Example: Creating File Names

- Suppose we want to create five files, `q1.pdf` through `q5.pdf`, consisting of histograms of 100 $N\left(0, i^2\right)$ random variables. We could execute the following code:

```r
for (i in 1:5) {
  fname <- paste("q",i,".pdf")
  pdf(fname)
  hist(rnorm(100,sd=i))
  dev.off()
}
```

Dates

Why do we need date/time classes?



COMPARATIVE TIME-TABLE,

SHOWING THE TIME AT THE PRINCIPAL CITIES OF THE UNITED STATES.

COMPARED WITH NOON AT WASHINGTON, D. C.

There is no "Standard Railroad Time" in the United States or Canada; but each railroad company adopts independently the time of its own locality, or of that place at which its principal office is situated. The inconvenience of such a system, if system it can be called, must be apparent to all, but is most annoying to persons strangers to the fact. From this cause many miscalculations and misconnections have arisen, which not unfrequently have been of serious consequcnce to individuals, and have, as a matter of course, brought into disrepute all Railroad-Guides, which of necessity give the local times. In order to relieve, in some degree, this anomaly in American railroading, we present the following table of local time, compared with that of Washington, D. C.

NOON AT WASHINGTON, D. C.	NOON AT WASHINGTON, D. C.	NOON AT WASHINGTON, D. C.
Albany, N. Y......12 14 P.M.	Indianapolis, Ind..11 26 A.M.	Philadelphia, Pa...12 08 P.M.
Augusta Ga.......11 41 A.M.	Jackson, Miss......11 08 "	Pittsburg, Pa......11 48 A.M.
Augusta, Me. .....11 31 "	Jefferson, Mo.......11 00 "	Plattsburg, N. Y..12 15 P.M.
Baltimore, Md.....12 02 P.M.	Kingston, Can.....12 02 P.M.	Portland, Me......12 28 "
Beaufort, S. C.....11 47 A.M.	Knoxville, Tenn...11 33 A.M.	Portsmouth, N. H.12 25 "
Boston, Mass......12 24 P.M.	Lancaster, Pa.....12 03 P.M.	Pra. du Chien, Wis.11 04 A.M.
Bridgeport, Ct.....12 16 "	Lexington, Ky.....11 31 A.M.	Providence, R. I...12 23 P.M.
Buffalo, N. Y......11 53 A.M.	Little Rock, Ark...11 00 "	Quebec, Can.......12 23 "
Burlington, N. J...12 09 P.M.	Louisville, Ky.....11 26 "	Racine, Wis.......11 18 A.M.
Burlington, Vt....12 16 "	Lowell, Mass......12 23 P.M.	Raleigh, N. C.. ...11 53 "
Canandaigua, N. Y.11 59 A.M.	Lynchburg, Va....11 51 A.M.	Richmond, Va.....11 58 "
Charleston, S. C...11 49 "	Middletown, Ct....12 18 P.M.	Rochester, N. Y...11 57 "
Chicago, Ill.......11 18 "	Milledgeville, Ga...11 35 A.M.	Sacketts H'bor, NY.12 05 P.M.
Cincinnati, O......11 31 "	Milwaukee, Wis....11 17 A.M.	St. Anthony Falls ,.10 56 A.M.
Columbia, S. C.....11 44 "	Mobile, Ala........11 16 "	St. Augustine, Fla.11 42 "
Columbus, O......11 36 "	Montpelier, Vt.....12 18 P.M.	St. Louis, Mo......11 07 "
Concord, N. H.....12 23 P.M.	Montreal, Can.....12 14 "	St. Paul, Min......10 56 "
Dayton, O.........11 32 A.M.	Nashville, Tenn...11 21 A.M.	Sacramento, Cal... 9 02 "
Detroit, Mich......11 36 "	Natchez, Miss.....11 03 "	Salem, Mass.......12 26 P.M.
Dover, Del.........12 06 P.M.	Newark, N. J......12 11 P.M.	Savannah, Ga.....11 44 A.M.
Dover, N. H.......12 37 "	New Bedford, Mass.12 25 "	Springfield, Mass...12 18 P.M.
Eastport, Me......12 41 "	Newburg, N. Y....12 12 "	Tallahassee, Fla....11 30 A.M.
Frankfort, Ky.....11 30 A.M.	Newburyport, Ms..12 25 "	Toronto, Can......11 51 "
Frederick, Md.....11 59 "	Newcastle, Del....12 06 "	Trenton, N. J.....,.12 10 P.M.
Fredericksburg, Va.11 58 "	New Haven, Conn..12 17 "	Troy, N. Y........12 14 "
Frederickton, N. Y.12 42 P.M.	New London, " ..12 20 "	Tuscaloosa, Ala....11 18 A.M.
Galveston, Texas ..10 49 A.M.	New Orleans, La...11 08 A.M.	Utica, N. Y.......12 08 P.M.
Gloucester, Mass..12 26 P.M.	Newport, R. I......12 23 P.M.	Vandalia, Ill.......11 18 A M.
Greenfield, " ..12 18 "	New York, N. Y...12 12 "	Vincennes, Ind....11 19 "
Hagerstown, Md...11 58 A.M.	Norfolk, Va.......12 03 "	Wheeling, Va......11 45 "
Halifax, N. S......12 54 P.M.	Northampton, Ms..12 18 "	Wilmington, Del...12 06 P.M.
Harrisburg, Pa....12 01 "	Norwich, Ct.......12 20 "	Wilmington, N. C..11 56 A.M.
Hartford, Ct.......12 18 "	Pensacola, Fla.....11 20 A.M.	Worcester, Mass...12 21 P.M.
Huntsville, Ala....11 21 A.M.	Petersburg, Va....11 59 "	York, Pa..........12 02 "

By an easy calculation, the difference in time between the several places above named may be ascertained. Thus, for instance, the difference of time between New York and Cincinnati may be ascertained by simple comparison, that of the first having the Washington noon at 12 12 P. M., and of the latter at 11 31 A. M.; and hence the difference is 43 minutes, or, in other words, the noon at New York will be 11.17 A. M. at Cincinnati, and the noon at Cincinnati will be 12 43 P. M. at New York. Remember that places *West* are "slower" in time than those *East* and *vice versa*.

Date Classes in R

- `Date` is in `yyyy-mm-dd` format and represents the number of days since Jamuary 1, 1970
- `POSIXct` represents the (signed) number of seconds since Jamuary 1, 1970 (in the UTC time zone) as a numeric vector.
- `POSIXlt` is a named list of vectors representing `sec`, `min`, `hour`, `mday`, `mon`, `year`, time zone par maters, and a few other items.

```r
x <- Sys.time()  # clock time as a POSIXct object
x; as.numeric(x)
```

```
## [1] "2017-11-02 11:07:12 PDT"
```

```
## [1] 1509646033
```

Creating Dates

- Typically, dates come into `R` as character strings.
- By default, `R` assumes the string is in the format `yyyy-mm-dd` or `yyyy-mm-dd`

```r
mychar <- "2017-10-05"
mydate <- as.Date(mychar)
str(mydate)
```

```
##  Date[1:1], format: "2017-10-05"
```

Date Formats

- R can parse many other types of date formats.
- See ?strptime for details.

```r
mychar <- "October 5th, 2017"
mydate <- as.Date(mychar, format = "%B %eth, %Y")
str(mydate)
```

```
##  Date[1:1], format: "2017-10-05"
```

Extract Parts of a Date Object

```r
mydate <- as.Date("2017-10-05")
weekdays(mydate)
```

```
## [1] "Thursday"
```

```r
months(mydate)
```

```
## [1] "October"
```

```r
quarters(mydate)
```

```
## [1] "Q4"
```

Generate Regular Sequences of Dates

```r
## first days of years
seq(as.Date("2007/1/1"), as.Date("2010/1/1"), "years")
```

```
## [1] "2007-01-01" "2008-01-01" "2009-01-01" "2010-01-01"
```

```r
## by month
seq(as.Date("2000/1/1"), by = "month", length.out = 4)
```

```
## [1] "2000-01-01" "2000-02-01" "2000-03-01" "2000-04-01"
```

```r
## quarters
seq(as.Date("2000/1/1"), as.Date("2001/1/1"), by = "quarte
```

```
## [1] "2000-01-01" "2000-04-01" "2000-07-01" "2000-10-01"
```

Time Intervals / Differences

- Function difftime calculates a difference of two date/time objects and returns an object of class “difftime” with an attribute indicating the units.

```r
time1 <- as.Date("2017-10-05")
time2 <- as.Date("2008-07-08")
time1 - time2
```

```
## Time difference of 3376 days
```

```r
difftime(time1, time2, units = "weeks")
```

```
## Time difference of 482.2857 weeks
```

Dates in Microsoft Excel

- Microsoft Excel stores dates as the number of days since Decemeber 31, 1899.
- However, Excel also incorrectly assumes that the year 1900 is a leap year to allow for compatability with Lotus 1-2-3.
- Therefore, for dates after 1901, set the origin to Decemeber 30, 1899 to convert an Excel date to an R date.

```r
as.Date(43013, origin = "1899-12-30")
```

```
## [1] "2017-10-05"
```

Lubridate

Lubridate

- Lubridate is an R package that makes it easier to work with dates and times.
- Lubridate was created by Garrett Grolemund and Hadley Wickham.

```r
# install.packages("lubridate")
library(lubridate)
```

```
##
## Attaching package: 'lubridate'

## The following object is masked from 'package:base':
##
##     date
```

Parse a date

- Lubridate accepts lots of formats

```r
ymd("20110604")
```

```
## [1] "2011-06-04"
```

```r
mdy("06-04-2011")
```

```
## [1] "2011-06-04"
```

```r
dmy("04/06/2011")
```

```
## [1] "2011-06-04"
```

Parse a date and time

```r
ymd_hms("2011-06-04 12:00:00", tz = "Pacific/Auckland")
```

```
## [1] "2011-06-04 12:00:00 NZST"
```

Extraction

```
arrive <- ymd_hms("2011-06-04 12:00:25")
second(arrive)
```

```
## [1] 25
```

```
second(arrive) <- 45
arrive
```

```
## [1] "2011-06-04 12:00:45 UTC"
```

Intervals

```r
arrive <- ymd_hms("2011-06-04 12:00:00")
leave <- ymd_hms("2011-08-10 14:00:00")
interval(arrive, leave)
```

```
## [1] 2011-06-04 12:00:00 UTC--2011-08-10 14:00:00 UTC
```

Arithmetic

```
mydate <- ymd("20130130")
mydate + days(2)
```

```
## [1] "2013-02-01"
```

```
mydate + months(5)
```

```
## [1] "2013-06-30"
```

Arithmetic

```r
mydate <- ymd("20130130")
mydate + days(1:5)
```

```
## [1] "2013-01-31" "2013-02-01" "2013-02-02" "2013-02-03"
```

End of (next) month

```r
jan31 <- ymd("2013-01-31")
jan31 + months(1)
```

```
## [1] NA
```

```r
ceiling_date(jan31, "month") - days(1)
```

```
## [1] "2013-01-31"
```

```r
floor_date(jan31, "month") + months(2) - days(1)
```

```
## [1] "2013-02-28"
```

Time Series Data in `R` (`xts`)

What is a Time Series?

- A time series is a set of observations x_t, each one being recorded at a specified time t.

Key R Time Series Packages

- `xts`: eXtensible Time Series.
- `zoo`: Z's Ordered Observations.
  - Both were created by Achim Zeileis.
- `lubridate`

What is xts?

- xts is an extended zoo object.
- A zoo object is a matrix with a vector of times that form an index.

```r
library(xts)
# xts is a matrix plus an index
x <- matrix(1:4, nrow=2, ncol=2)
idx <- seq(as.Date("2016-10-27"), length=2, by="days")
x_xts <- xts(x, order.by = idx)
x_xts
```

```
##            [,1] [,2]
## 2016-10-27    1    3
## 2016-10-28    2    4
```

Constructing `xts`

- The function `xts()` gives you a few other options as well.
  - See `?xts`.
  - `unique` forces times to be unique.
  - `tzone` sets the time zone of the series.
- The index should be of class Date, POSIX, timeDate, chron, etc.
- If the dates are not in chronological order, the `xts` constructor will automatically order the time series.
- Since `xts` is a subclass of `zoo`, `xts` gives us all the functionality of `zoo`.

Deconstructing xts

- How do we get the original index and matrix back?
    - coredata extracts the matrix.
    - index extracts the index.

```r
coredata(x_xts)  # Gives us a martix
```

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

```r
index(x_xts)  # Gives us a vector of dates
```

```
## [1] "2016-10-27" "2016-10-28"
```

Viewing the structure of an xts Object.

- The `str()` function compactly displays the internal structure of an R object.

```r
str(x_xts)
```

```
## An 'xts' object on 2016-10-27/2016-10-28 containing:
##   Data: int [1:2, 1:2] 1 2 3 4
##   Indexed by objects of class: [Date] TZ: UTC
##   xts Attributes:
##  NULL
```

Importing and Exporting Time Series

- Importing:
  1. Read data into `R` using one of the usual functions.
     - `read.table()`, `read.xts()`, `read.zoo()`, etc.
  2. `as.xts()` converts `R` objects to `xts`.
- Exporting:
  - `write.zoo(x, "file")` for text files.
  - `saveRDS(x, "file")` for future use in `R`.

Subsetting Time Series

- xts supports one and two-sided intervals.

```
# Load fund data
data(edhec, package = "PerformanceAnalytics")
edhec["2007-01/2007-02", 1]  # interval
```

```
##            Convertible Arbitrage
## 2007-01-31                0.0130
## 2007-02-28                0.0117
```

```
head(edhec["2007-01/", 1], n = 5)  # start in January 2007
```

```
##            Convertible Arbitrage
## 2007-01-31                0.0130
## 2007-02-28                0.0117
## 2007-03-31                0.0060
## 2007-04-30                0.0026
## 2007-05-31                0.0110
```

Truncated Dates

- `xts` allows you to truncate dates

```
# January 2007 to March
edhec["200701/03", 1]  # interval
```

```
##            Convertible Arbitrage
## 2007-01-31                0.0130
## 2007-02-28                0.0117
## 2007-03-31                0.0060
```

Other Ways to Extract Values

- We can subset `xts` objects with vectors of integers, logicals, or dates.

```
edhec[c(1,2), 1]  # integers
```

```
##            Convertible Arbitrage
## 1997-01-31                0.0119
## 1997-02-28                0.0123
```

```
edhec[(index(edhec) < "1997-02-28"), 1]  # a logical vecto
```

```
##            Convertible Arbitrage
## 1997-01-31                0.0119
```

```
edhec[c("1997-01-31","1997-02-28") , 1]  # a date vector
```

```
##            Convertible Arbitrage
## 1997-01-31                0.0119
```

first() and last() Functions

- R uses head() and tail() to look at the start and end of a series.
  - i.e. “the first 3 rows” or “the last 6 rows”.
- xts has two functions first() and last().
  - i.e. “the first 6 days” or “the last 6 months”

```
first(edhec[, "Convertible Arbitrage" ], "3 months")
```

```
##            Convertible Arbitrage
## 1997-01-31                0.0119
## 1997-02-28                0.0123
## 1997-03-31                0.0078
```

Math Operations

- Math operations are on the intersection of times.

```
x <- edhec["199701/02", 1]
y <- edhec["199702/03", 1]
z <- edhec["199703/04", 1]
x + y # only the intersection
```

```
##            Convertible.Arbitrage
## 1997-02-28                0.0246
```

Operations on the Union

```r
x + merge(y, index(x), fill = 0)
```

```
##            Convertible.Arbitrage
## 1997-01-31                0.0119
## 1997-02-28                0.0246
```

```r
x + merge(y, index(x), fill = na.locf)
```

```
##            Convertible.Arbitrage
## 1997-01-31                    NA
## 1997-02-28                0.0246
```

Database Joins

- There are four main database joins: inner, outer, left and right joins.
  - inner join: intersection.
  - outer join: union.
  - left: using times from the left series.
  - right: using times from the right series.

Merging `xts` objects

- We can merge `xts` objects using the `merge` function.
- `merge` takes three arguments.
  - an arbitrary number of time series.
  - `fill`, which handles missing data.
  - `join`, the type of join we want to do. The default is *outer* join.

```
colnames(x) <- "x"; colnames(y) <- "y"; colnames(z) <- "z"
merge(x, y, z)
```

```
##                 x      y      z
## 1997-01-31 0.0119     NA     NA
## 1997-02-28 0.0123 0.0123     NA
## 1997-03-31     NA 0.0078 0.0078
## 1997-04-30     NA     NA 0.0086
```

Merging xts Objects: Left and Right Joins

```r
merge(x, y, join='left')
```

```
##                 x      y
## 1997-01-31 0.0119     NA
## 1997-02-28 0.0123 0.0123
```

```r
merge(x, y, join='right')
```

```
##                 x      y
## 1997-02-28 0.0123 0.0123
## 1997-03-31     NA 0.0078
```

Missing Data

- `locf`: last observation carried forward

```r
x <- c(1, NA, NA, 4)
idx <- seq(as.Date("2016-10-27"), length=4, by="days")
x <- xts(x, order.by = idx); colnames(x) <- "x"
cbind(x, na.locf(x), na.locf(x, fromLast = TRUE))
```

```
##             x x.1 x.2
## 2016-10-27  1   1   1
## 2016-10-28 NA   1   4
## 2016-10-29 NA   1   4
## 2016-10-30  4   4   4
```

Other NA Options

```r
na.fill(x, -999)
```

```
##               x
## 2016-10-27    1
## 2016-10-28 -999
## 2016-10-29 -999
## 2016-10-30    4
```

```r
na.omit(x)
```

```
##            x
## 2016-10-27 1
## 2016-10-30 4
```

Interpolate NAs

- Missing values (`NAs`) are replaced by *linear* interpolation via `approx` or *cubic spline* interpolation via `spline`, respectively.

```r
na.approx(x)
```

```
##            x
## 2016-10-27 1
## 2016-10-28 2
## 2016-10-29 3
## 2016-10-30 4
```

```r
# na.spline(x) gives the same results in this example
```

Lagging a Time Series

- `lag(x, k = 1, na.pad = TRUE)`
  - k is the number of lags (positive = forward and negative = backward)
  - k can be a vector of lags
  - ‘na.pad’ pads the vector back to the original size

```
x <- na.approx(x)
cbind(x, lag(x,1), lag(x,-1))
```

```
##            x x.1 x.2
## 2016-10-27 1  NA   2
## 2016-10-28 2   1   3
## 2016-10-29 3   2   4
## 2016-10-30 4   3  NA
```

Diffferencing Series

- Differencing converts levels to changes.
- see `diff.xts` for additional function arguments.

```
x <- na.approx(x)
cbind(x, diff(x))
```

```
##            x x.1
## 2016-10-27 1  NA
## 2016-10-28 2   1
## 2016-10-29 3   1
## 2016-10-30 4   1
```

Apply over Time Periods

- `period.apply()` applys a function over time intervals.
- `endpoints` gives us the row numbers of endpoints.
- `apply.monthly`, `apply.daily`, `apply.quarterly`, etc. take care of the endpoint calculation for us.

```
edhec9701 <- edhec["1997/2001", c(1,3)]
# determine the endpoints
ep <- endpoints(edhec9701, "years")
period.apply(edhec9701, INDEX=ep, FUN=mean)
```

```
##            Convertible Arbitrage Distressed Securities
## 1997-12-31            0.01159167           0.013016667
## 1998-12-31            0.00270000          -0.001491667
## 1999-12-31            0.01251667           0.015225000
## 2000-12-31            0.01377500           0.004050000
## 2001-12-31            0.01086667           0.011525000
```

do.call: A Useful R Trick

- The do.call function allows us to specify the name of function, either as a character or an object, and provide arguments as a list.

```r
do.call(mean, args= list(1:10))
```

```
## [1] 5.5
```

```r
do.call("mean", args= list(1:10))
```

```
## [1] 5.5
```

Discrete Rolling Windows

- split, lapply a function (cumsum, cumprod, cummin, cummax), and recombine.

```
edhec.yrs <- split(edhec[,1], f="years")
edhec.yrs <- lapply(edhec.yrs, cumsum)
edhec.ytd <- do.call(rbind, edhec.yrs)
edhec.ytd["200209/200303", 1]
```

```
##            Convertible Arbitrage
## 2002-09-30                0.0322
## 2002-10-31                0.0426
## 2002-11-30                0.0677
## 2002-12-31                0.0834
## 2003-01-31                0.0283
## 2003-02-28                0.0416
## 2003-03-31                0.0505
```

Continuous Rolling Windows

- `rollapply(data, width, FUN, ...)`

```r
rollapply(edhec["200301/06", 1], 3, mean)
```

```
##            Convertible Arbitrage
## 2003-01-31                    NA
## 2003-02-28                    NA
## 2003-03-31            0.01683333
## 2003-04-30            0.01240000
## 2003-05-31            0.01250000
## 2003-06-30            0.00760000
```

Stock Market Data in `R`

Data from quantmod

- With quantmod we can download stock market data into xts objects.

```r
library(quantmod)
getSymbols("^GSPC", src="yahoo", from = "2008-01-01")
```

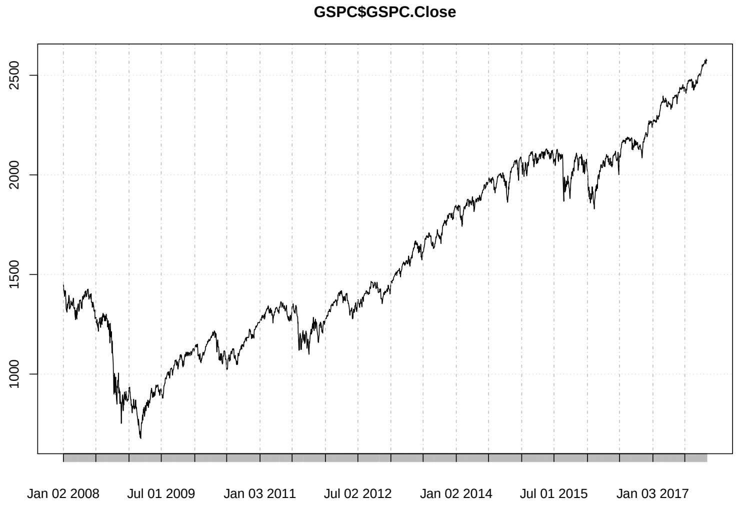
```
## [1] "GSPC"
```

```r
head(GSPC,3)[, 1:4]
```

```
##            GSPC.Open GSPC.High GSPC.Low GSPC.Close
## 2008-01-02   1467.97   1471.77  1442.07    1447.16
## 2008-01-03   1447.55   1456.80  1443.73    1447.16
## 2008-01-04   1444.01   1444.01  1411.19    1411.63
```

A Basic Plot

```r
plot(GSPC$GSPC.Close)
```



Switch Period

- `to.period` changes the periodicity of a univariate or OHLC (open, high, low, close) object.

```
eom <- to.period(GSPC,'months')
head(eom,3)
```

```
##            GSPC.Open GSPC.High GSPC.Low GSPC.Close GSPC.
## 2008-01-31   1467.97   1471.77  1270.05    1378.55 98475
## 2008-02-29   1378.60   1396.02  1316.75    1330.63 78536
## 2008-03-31   1330.45   1359.68  1256.98    1322.70 93189
##            GSPC.Adjusted
## 2008-01-31       1378.55
## 2008-02-29       1330.63
## 2008-03-31       1322.70
```

Plotting in R

Motivation

One skill that isn't taught in grad school is how to make a nice chart.

- Managing Director at Citigroup

What makes a chart nice?

- The reader should look at the chart and immediately understand what data are displayed.
- This means we need:
  - A clear title.
  - Clear labels for each axis (scale and units).
  - A legend if more than one time series is displayed.
  - Different colors and line formats for different time series.
  - Grid lines.
  - Labels.

Plotting Facilities in `R`

- R has excellent plotting methods built-in.
- I will focus on base `R`.
- As a next step, I recommend learning `ggplot2`, an excellent plotting package.
- http://www.r-graph-gallery.com/

Basic Plotting

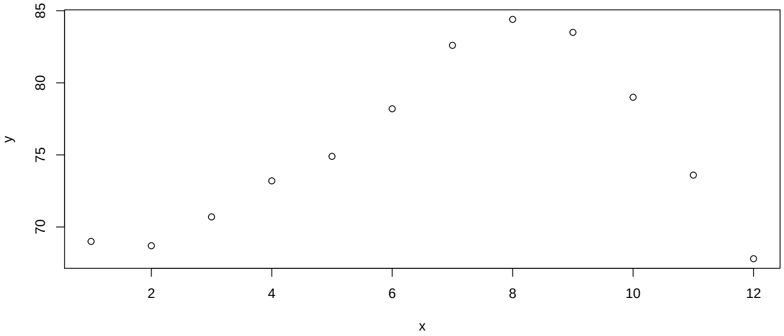
- `example(plot)`
- `example(hist)`
- `?par`
- `?plot.default`

The `plot()` Function

- `plot()` is generic function, i.e. a placeholder for a family of functions.
  - the function that is actually called depends on the class of the object on which it is called.
- `plot()` works in stages.
  - you can build up a graph in stages by issuing a series of commands.
- We will see how this works with an example.

A Basic Plot

```r
x <- seq(1:12)
y <- c(69, 68.7, 70.7, 73.2, 74.9, 78.2,
       82.6, 84.4, 83.5, 79, 73.6, 67.8)
plot(x, y)
```

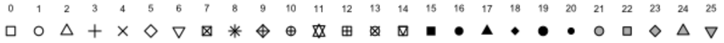


Graphical `par`amaters

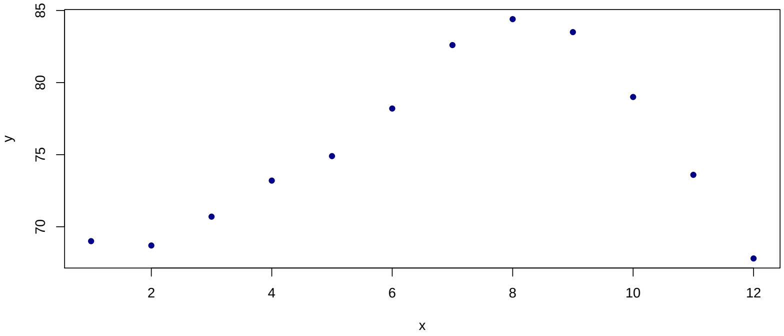
- Graphical parameters can be set as arguments to the `par` function, or they can be passed to the `plot` function.
- Make sure to read through `?par`.
- Some useful parameters:
  - `cex`: sizing of text and symbols
  - `pch`: point type.
  - `lty`: line type.
    - 0=blank, 1=solid (default), 2=dashed, 3=dotted, 4=dotdash, 5=longdash, 6=twodash
  - `lwd`: line width.
  - `mar`: margins.
  - `bg`: background color

pch

- pch sets how points are displayed



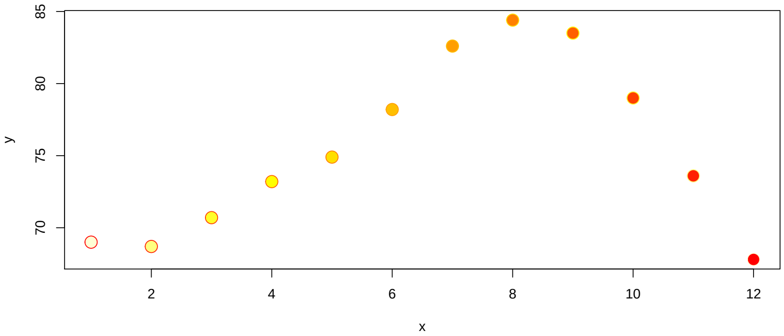
```r
plot(x,y, pch = 16, col='darkblue')
```



Colors in R

- `colors()` returns all available color names.
- `rainbow(n)`, `heat.colors(n)`, `terrain.colors(n)` and `cm.colors(n)` return a vector of `n` contiguous colors.

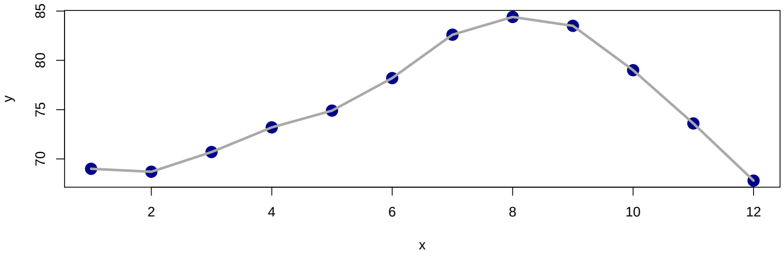
```r
plot(x, y, pch = 21, col=heat.colors(12),
     cex = 2, bg = rev(heat.colors(12)))
```



`lines()`

- `lines()` takes coordinates and joins the corresponding points with line segments.
  - Notice, by calling `lines` after `plot` the line is on top of the points.
  - This is why we want to build the plot in stages.

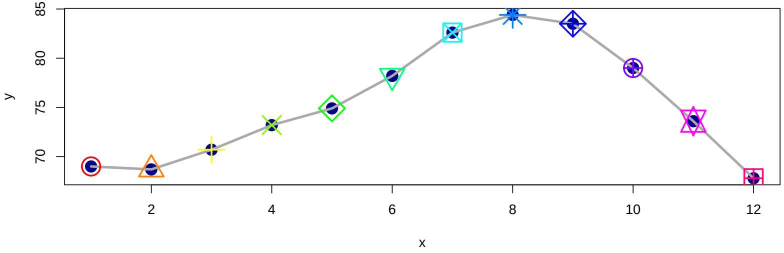
```r
plot(x,y, pch = 16, col='darkblue', cex=2)
lines(x, y, col='darkgrey', lwd = 3)
```



points()

- points is a generic function to draw a sequence of points at the specified coordinates. The specified character(s) are plotted, centered at the coordinates.

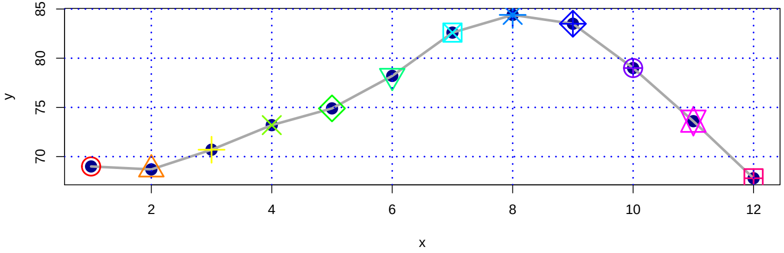
```
plot(x,y, pch = 16, col='darkblue', cex=2)
lines(x, y, col='darkgrey', lwd = 3)
points(x, y, col=rainbow(12), pch=1:12, cex=3, lwd=2)
```



grid()

- grid adds a rectangular grid to an existing plot.
- ?grid for more details.

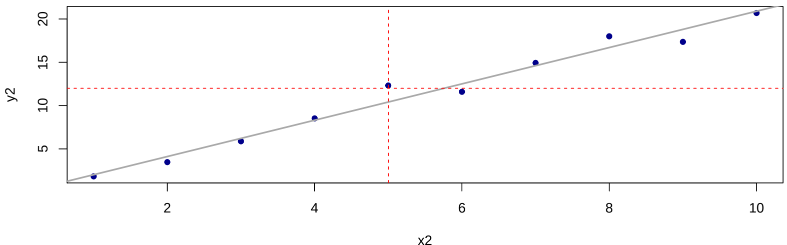
```r
plot(x,y, pch = 16, col='darkblue', cex=2)
lines(x, y, col='darkgrey', lwd = 3)
points(x, y, col=rainbow(12), pch=1:12, cex=3, lwd=2)
grid(col="blue", lwd=2)
```



abline()

- abline adds one or more straight lines through the current plot.

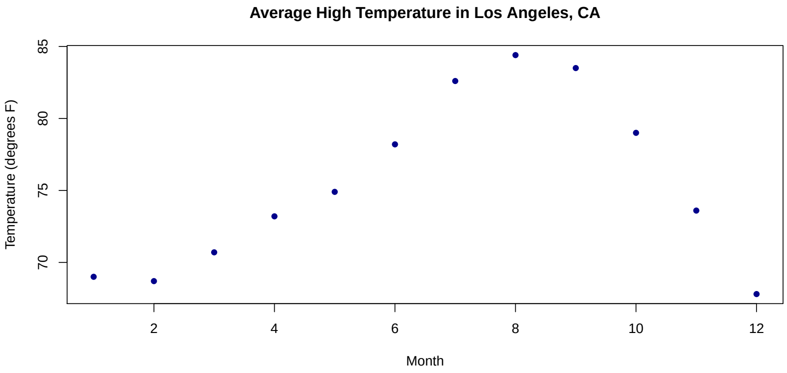
```r
x2 <- 1:10; y2 <- 1 + 2*x2 + rnorm(10)
plot(x2,y2, pch = 16, col='darkblue')
model <- lm(y2 ~ x2)
abline(model, col="darkgrey", lwd=2)
abline(v = 5 , col = "red", lty = 2)
abline(h = 12, col = "red", lty = 2)
```



Adding a Title in Lables

- Use the `main` argument for a title.
- Use the `xlab` and `ylab` for axis labels.

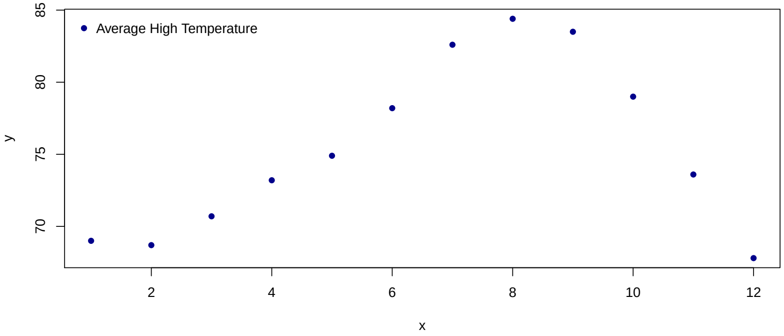
```
plot(x,y, pch = 16, col='darkblue',
     xlab = "Month", ylab = "Temperature (degrees F)",
     main = "Average High Temperature in Los Angeles, CA")
```



Adding a Legend: The `legend()` Function

- see `?legend` and `example(legend)`

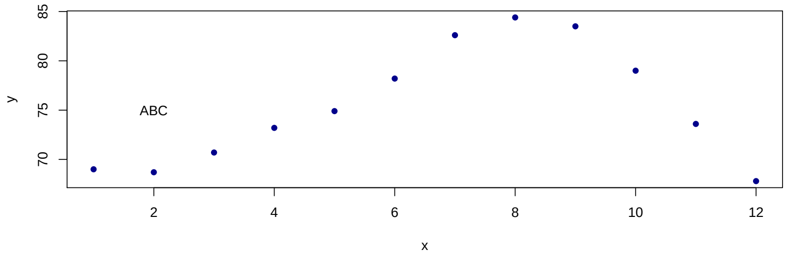
```
plot(x,y, pch = 16, col='darkblue')
legend("topleft", inset=.01, "Average High Temperature",
  col = "darkblue", pch = 16, bg="white",box.col="white")
```



text() and locator()

- Use the text() function to add text anywhere in the current graph.
- locator() allows you to click on a point in the chart and returns the location.

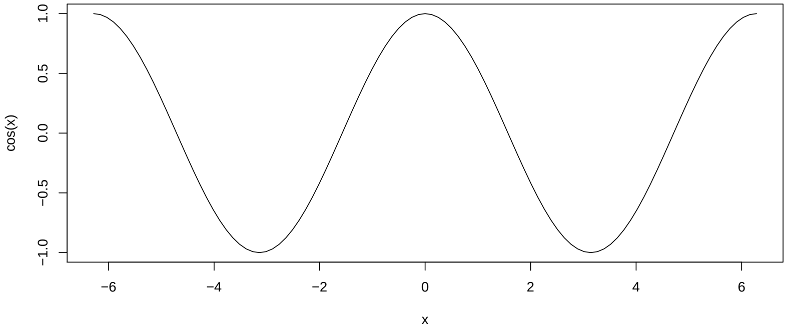
```r
plot(x,y, pch = 16, col='darkblue')
text(2,75, "ABC")
```



curve()

- With curve(), you can plot a function.

```r
curve(cos(x), -2*pi, 2*pi)
```



Saving a Plot to a File

- Saving a plot to a pdf file:
    - Open a file: `pdf("FileName.pdf", width, height,...)`
    - Create the plot.
    - Close the device with `dev.off()`
- You can use `dev.copy()` to save the displayed graph.
- See `library(help = "grDevices")` for more information.

An Example of Plotting in R

- Let's plot the cumulative (gross) return of IBM and the S&P 500 since 1980.

```
library(quantmod)
getSymbols(c("^GSPC", "IBM"), src="yahoo",
           from = "1979-12-31")
```

```
## [1] "GSPC" "IBM"
```

```
adj_close <- merge(GSPC$GSPC.Adjusted, IBM$IBM.Adjusted)
daily_returns <- diff(adj_close)/lag(adj_close)
cum_ret <- cumprod(1+daily_returns[-1,])
ret1 <- xts(matrix(1, ncol=2), as.Date("1979-12-31"))
cum_ret <- (rbind(cum_ret, ret1) - 1)*100
colnames(cum_ret) <- c("GSPC", "IBM")
```

The Data

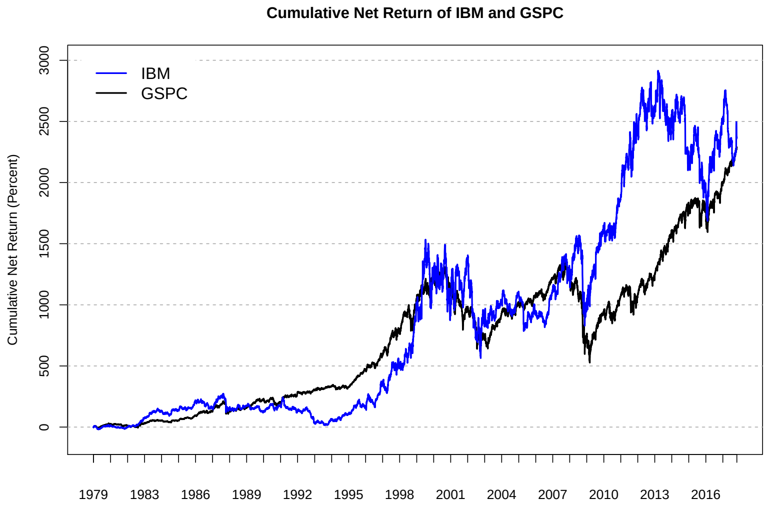
```r
head(cum_ret, 9)
```

```
##                  GSPC       IBM
## 1979-12-31  0.0000000  0.000000
## 1980-01-02 -2.0196405 -2.912548
## 1980-01-03 -2.5199194 -1.359205
## 1980-01-04 -1.3155503 -1.553311
## 1980-01-07 -1.0468816 -1.941698
## 1980-01-08  0.9357004  4.660284
## 1980-01-09  1.0283500  1.553471
## 1980-01-10  1.8065564  4.854470
## 1980-01-11  1.8343487  4.077727
```

Start with a Blank Chart and Build it Up

```
plot(cum_ret$IBM, xlab="", ylab = "Cumulative Net Return (
     main="", major.ticks="years", minor.ticks=F,
     type="n", major.format = "%Y", auto.grid=F,
     ylim = c(-500, 3000))
abline(h=seq(-500,3000,500), col="darkgrey", lty=2)
lines(cum_ret$GSPC, col="black", lwd=2)
lines(cum_ret$IBM, col="blue", lwd=2)
legend("topleft", inset=.02,
       c("IBM","GSPC"), col=c("blue", "black"),
       lwd=c(2,2),bg="white", box.col="white")
```

The Chart



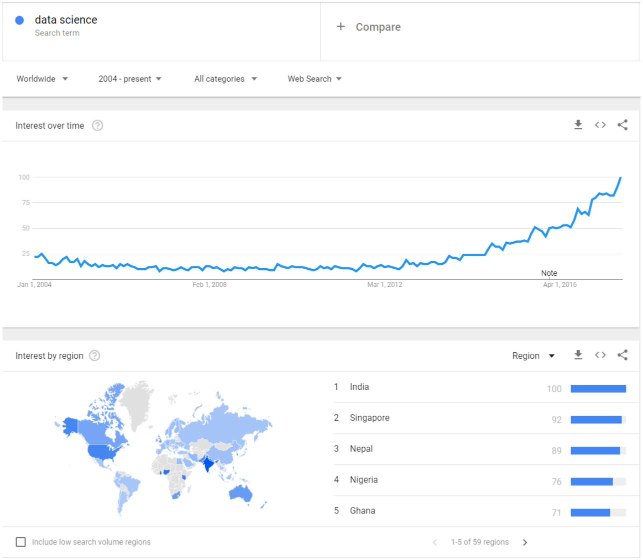
Cumulative Net Return of IBM and GSPC
IBM
GSPC
Cumulative Net Return (Percent)
0
500
1000
1500
2000
2500
3000
1979
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
2016

An Example from Google Trends

Google Trends

- Google Trends is a useful way to compare changes in popularity of certain search terms over time.
- Google Trends data can be used as a proxy for all sorts of difficult-to-measure quantities like economic activity and disease propagation.
- Let's download data on search activity for the key word, "Data Science".
  - See the `.csv` file named `multiTimline.csv`.

Interest in Data Science over Time



● data science
Search term

+ Compare

Worldwide ▾ 2004 - present ▾ All categories ▾ Web Search ▾

Interest over time

Interest by region

Region ▾

1	India	100
2	Singapore	92
3	Nepal	89
4	Nigeria	76
5	Ghana	71

☐ Include low search volume regions

1-5 of 59 regions

Loading the Data into R

- First, we load the data into R:

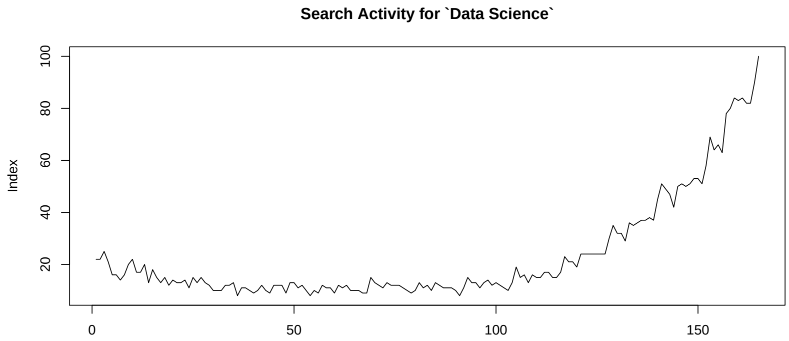
```r
dataScience = read.csv(file = "./multiTimeline.csv",
           header = T, skip = 2, stringsAsFactors = F)
colnames(dataScience) = c("date", "interest")
str(dataScience)
```

```
## 'data.frame':    165 obs. of  2 variables:
##  $ date    : chr  "2004-01" "2004-02" "2004-03" "2004-0
##  $ interest: int  22 22 25 21 16 16 14 16 20 22 ...
```

First attempt at a Plot

- Without a x-axis, R treats the data as equally-spaced.

```
plot(dataScience$interest, type = 'l',
     ylab = "Index",xlab="",
     main = "Search Activity for `Data Science`")
```



Convert the Date String to a Date Class

- The month column does not have a day and we need to add a day to convert it to a date.
- Let's use the first day of the month

```r
dataScience$date = paste0(dataScience$date, "-01")
str(dataScience)
```

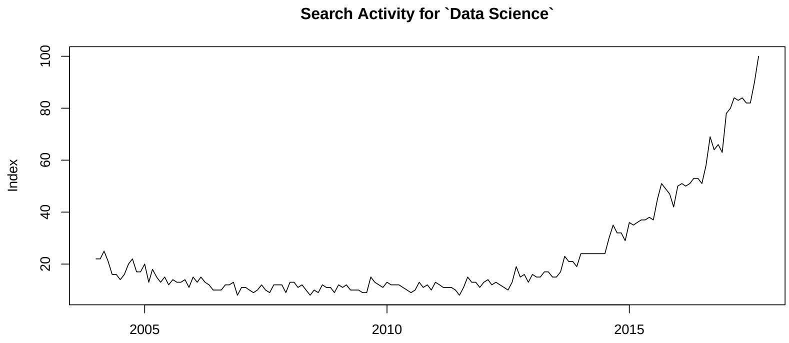
```
## 'data.frame':    165 obs. of  2 variables:
##  $ date    : chr  "2004-01-01" "2004-02-01" "2004-03-01'
##  $ interest: int  22 22 25 21 16 16 14 16 20 22 ...
```

```r
dataScience$date = as.Date(dataScience$date,
                           format = "%Y-%m-%d")
```

A Plot with Dates: Default Axis

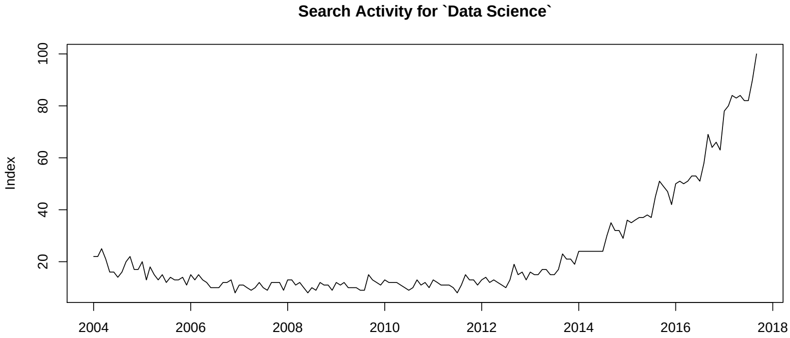
- The default spacing of 5 years seems too large.

```r
plot(dataScience$date, dataScience$interest, type = 'l',
     ylab = "Index", xlab = "",
     main = "Search Activity for `Data Science`")
```



A Plot with Dates: Custom Axis

```r
plot(dataScience$date, dataScience$interest, type = 'l',
     ylab = "Index", xlab = "",  xaxt = 'n',
     main = "Search Activity for `Data Science`")
dts = seq(from = as.Date("2004-01-01"),
          to = as.Date("2018-01-01"), by="2 years")
axis(1, at=dts, labels=format(dts, "%Y"))
```



Lab

Lab 2

- Let's work on Lab 2.