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 in R (`xts`)

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.

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`.

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

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

paste()

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

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

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

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

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

```r
# 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`.

```r
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:

```
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 consequence 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] "2017-10-26 11:02:15 PDT"
```

```
## [1] 1509040935
```

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`

```
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.

```
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

```
## 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"
```

```
## 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"
```

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

```
## [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.

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

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

```
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.

```
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

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

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

Extraction

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

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

```r
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

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

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

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

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

Arithmetic

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

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

End of (next) month

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

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

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

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

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

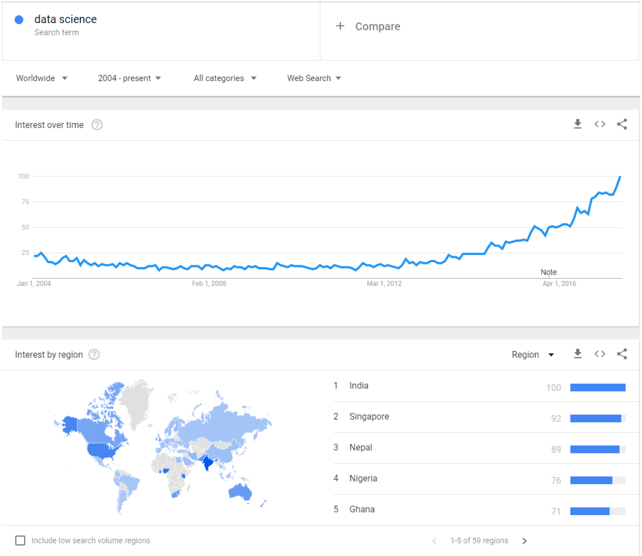
```
## [1] "2013-02-28"
```

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



Loading the Data into R

- First, we load the data into R:

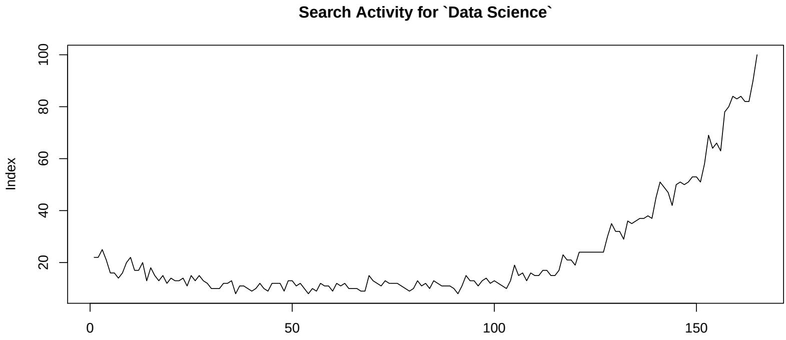
```
dataScience = read.csv(file = "./multiTimeline.csv",
          header = T, skip = 2, stringsAsFactors = F)
colnames(dataScience) = c("date", "interest")
str(dataScience)
```

```
## 'data.frame':    165 obs. of  2 variables:
##  $ date    : chr  "2004-01" "2004-02" "2004-03" "2004-04
##  $ 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

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

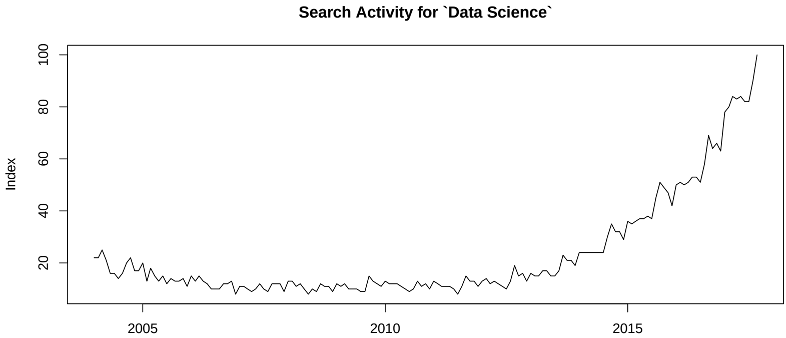
```
## 'data.frame':    165 obs. of  2 variables:
##  $ date    : chr  "2004-01-01" "2004-02-01" "2004-03-01'
##  $ interest: int  22 22 25 21 16 16 14 16 20 22 ...
```

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

A Plot with Dates: Default Axis

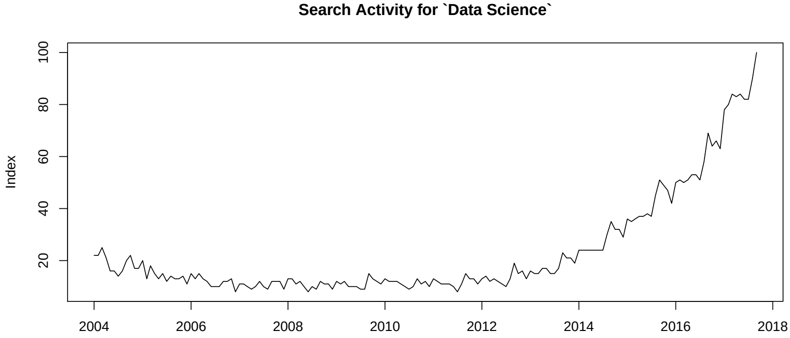
- The default spacing of 5 years seems too large.

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



A Plot with Dates: Custom Axis

```
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"))
```



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`
  - Created by Garrett Grolemund and Hadley Wickham.

Date Classes in R

- `Date` is in `yyyy-mm-dd` format.
- `POSIXct` represents the (signed) number of seconds since the beginning of 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
```

```
## [1] "2017-10-26 11:02:16 PDT"
```

```r
class(x)
```

```
## [1] "POSIXct" "POSIXt"
```

What is xts?

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

```
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.

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

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

```
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.

```r
# 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
```

```r
head(edhec["2007-01/", 1])  # 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

```r
# 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"

```r
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]
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.

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

```
##                 x      y
## 1997-01-31 0.0119     NA
## 1997-02-28 0.0123 0.0123
## 1997-03-31     NA 0.0078
```

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

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

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

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.

```r
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.

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

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

```
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
```