Rapid Trade Development

Leveraging *R* with xts and quantmod for quantitative trading

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Department of Statistics and Mathematics
Vienna University of Economics and Business Administration

What is quantitative trading?

What is quantitative trading?

A programmatic/automated process to execute trades based on mathematical or statistical logic.

Quant Trading Components

Ideas

Strategy Dev

Market Data

Back-testing

Risk Analysis

Forward-testing

Execution

Performance Analysis

Reports

Quant Trading Components

Ideas

Strategy Dev

Market Data

E

ysis

Forward testing

Execution

Performance Analysis

Reports

Can this be done in one language?

It can in R!

Advantages to R

Powerful language out of the box

Huge financial community use and contributions

Vector-based data and processing (time-series)

Unequaled statistical toolkit (base + CRAN)

Strong academic research usage

Open source - customization and validation

Easy to integrate with external data stores

Extensibility with C, Fortran, C++, etc

Flexible graphics on-screen and off

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What was missing for trading?

A trader-oriented workflow

Standard financial visualization tools

Native tools for managing [large] time series quickly

Connections to real-time data feeds (Bloomberg, IB, DTN)

Connections to industry data stores (Vhayu, OneTick, Kdb)

Wide-spread adoption & visibility

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xts

xts: extensible time series

Most everything in trading involves a time series

Regular data (positions data, P&L)

Irregular data (market data, book data, trades)

R has many ways to manage this...

xts: extensible time series

Data Classes

xts: extensible time series

fts

Data Classes

matrix

mts

tframe

data.table

data.frame

zoo

its

ts

irts

timeSeries

zooreg

vectors

xts: extensible time series

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Time Classes

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xts: extensible time series

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Sometimes, choice is **bad** for package developers and interoperability

character

Time Classes

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POSIXlt

numeric

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xts: extensible time series

The "solution" ?

xts: extensible time series

add one more class *of course*...

Motivation (c. 2007)

Avid user of zoo

- Natural R-like interface
- Flexible and complete methods
- S3!

I still wanted a few features for trading...

- Additional series metadata
- Require time-based indexing
- Conversion/reconversion tools

xts: extensible time series

Significant design requirements for xts:

- Preserve zoo behavior
- Utilize time-based indexing
- Allow for arbitrary attributes to be cleanly attached
- ISO 8601 subsetting by time strings
- Lossless conversion utilities to hide messy details

xts: extensible time series

What's inside an xts object?

Index + Matrix + Attr

Internally the storage is always a numeric vector!

Can be of any class supported by matrix

Hidden attributes AND user attributes

.indexCLASS, .indexFORMAT, .indexTZ, .CLASS, index

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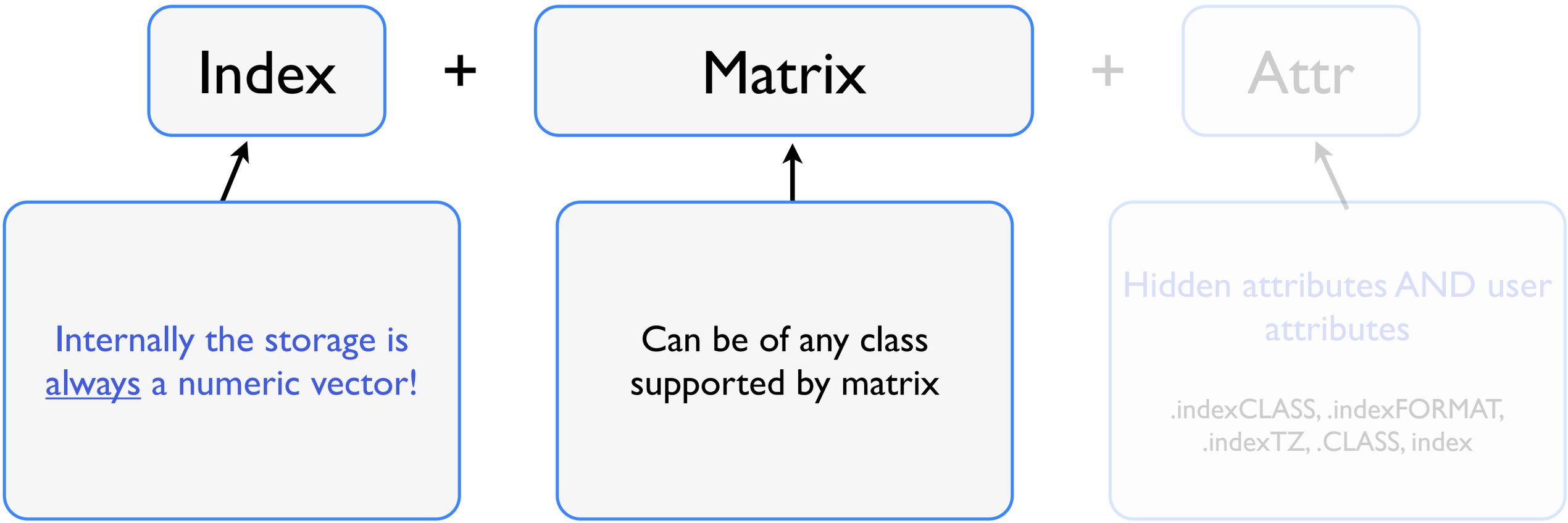

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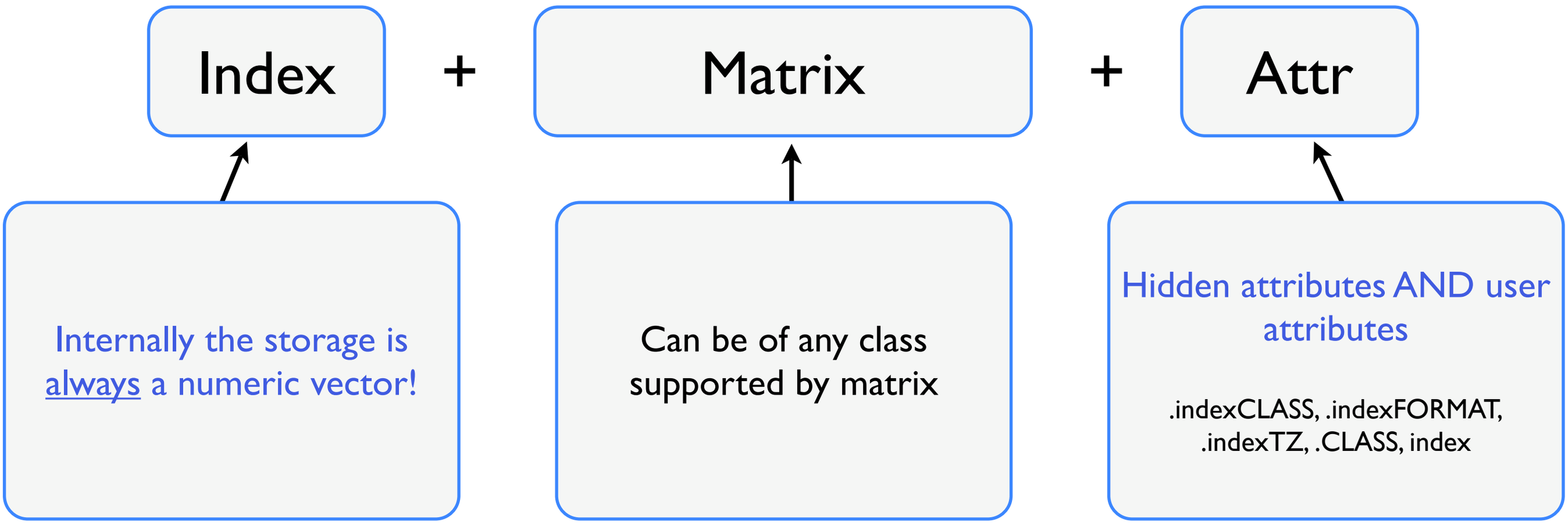

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Important! index must be a time-based class

xts: extensible time series

Index as numeric? That isn't "time-based"!!

- Internally all index values are represented in POSIX time (seconds since the epoch)
- Coercion happens at object creation or upon index replacement
- index() converts back to user-level class
- .index() access the raw seconds in the index
- .indexCLASS, .indexFORMAT and .indexTZ attributes
- Rationale? Simplicity for C level code, removal of multiple conversion in most instances, more consistent behavior
- All details are hidden from the user

Time-based indexing in xts (ISO 8601)

- Date and time organized from *most significant to least significant:* CCYY-MM-DD HH:MM:SS[.s]
- Fixed number of digits
- Separators can be omitted e.g. CCYYMMDDHHMMSS
- Reduced accuracy forms are valid: e.g. CCYY-MM
- Fractional decimal time is supported
- Intervals can be expressed e.g. 2000-05/2001-04

source: http://en.wikipedia.org/ISO_8601

Create an xts object

Load xts package

```
> library(xts)
Loading required package: zoo
xts now requires a valid TZ variable to be set
 your current TZ:America/Chicago

> x <- xts(rnorm(10), Sys.Date()+1:10)
> x
             [,1]
2009-03-24  0.3554788
2009-03-25  1.2812633
2009-03-26  0.1268833
2009-03-27 -0.6945146
2009-03-28 -0.3936148
2009-03-29 -0.1938840
2009-03-30  0.2368576
2009-03-31 -1.2152293
2009-04-01  0.8100493
2009-04-02  1.4152439
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2009-04-01  0.8100493
2009-04-02  1.4152439
```

Indexing by time

Index using standard tools (still works)

```
> x[ index(x) >= as.Date("2009-03-28") & index(x) <=
+  as.Date("2009-04-01") ]
                 [,1]
2009-03-28 -0.3936148
2009-03-29 -0.1938840
2009-03-30  0.2368576
2009-03-31 -1.2152293
2009-04-01  0.8100493

> x["20090328/20090401"]
                 [,1]
2009-03-28 -0.3936148
2009-03-29 -0.1938840
2009-03-30  0.2368576
2009-03-31 -1.2152293
2009-04-01  0.8100493
```

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```
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                [,1]
2009-03-28 -0.3936148
2009-03-29 -0.1938840
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2009-03-29 -0.1938840
2009-03-30  0.2368576
2009-03-31 -1.2152293
2009-04-01  0.8100493
```

Index via ISO-style with xts

Indexing by time

```
> x["2009"]
             [,1]
2009-03-24  0.3554788
2009-03-25  1.2812633
2009-03-26  0.1268833
2009-03-27 -0.6945146
2009-03-28 -0.3936148
2009-03-29 -0.1938840
2009-03-30  0.2368576
2009-03-31 -1.2152293
2009-04-01  0.8100493
2009-04-02  1.4152439
```

```
> x["200904"]
             [,1]
2009-04-01 0.8100493
2009-04-02 1.4152439
```

```
> x["20090301/200903"]
             [,1]
2009-03-24  0.3554788
2009-03-25  1.2812633
2009-03-26  0.1268833
2009-03-27 -0.6945146
2009-03-28 -0.3936148
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2009-03-30  0.2368576
2009-03-31 -1.2152293
```

All of 2009

Indexing by time

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2009-03-24  0.3554788
2009-03-25  1.2812633
2009-03-26  0.1268833
2009-03-27 -0.6945146
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> x["200904"]
             [,1]
2009-04-01 0.8100493
2009-04-02 1.4152439
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> x["20090301/200903"]
             [,1]
2009-03-24  0.3554788
2009-03-25  1.2812633
2009-03-26  0.1268833
2009-03-27 -0.6945146
2009-03-28 -0.3936148
2009-03-29 -0.1938840
2009-03-30  0.2368576
2009-03-31 -1.2152293
```

All of April 2009

Indexing by time

```
> x["2009"]
             [,1]
2009-03-24  0.3554788
2009-03-25  1.2812633
2009-03-26  0.1268833
2009-03-27 -0.6945146
2009-03-28 -0.3936148
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```

From the first March to the end of March

xts: extensible time series

All subsetting is via a binary search algorithm. F-A-S-T!

```
> str(x10m) # 10 million observations
An 'xts' object from 2009-03-23 16:19:00 to 2009-07-17 10:05:39 containing:
  Data: int [1:10000000, 1] 1 2 3 4 5 6 7 8 9 10 ...
  Indexed by objects of class: [POSIXt,POSIXct] TZ: America/Chicago
  xts Attributes:
 NULL

> str(x100k) # 100 thousand observations
An 'xts' object from 2009-03-23 16:19:00 to 2009-03-24 20:05:39 containing:
  Data: int [1:100000, 1] 1 2 3 4 5 6 7 8 9 10 ...
  Indexed by objects of class: [POSIXt,POSIXct] TZ: America/Chicago
  xts Attributes:
NULL

> system.time(x10m['20090323'])
   user  system elapsed
  0.006   0.001   0.006
> system.time(x100k['20090323'])
   user  system elapsed
  0.006   0.001   0.006

> system.time(x10m[index(x10m) >= as.POSIXct('2009-03-23 16:19:00') & index(x10m) <=
   as.POSIXct('2009-03-23 23:59:58')])
   user  system elapsed
  1.457   1.372   2.832
```

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xts: extensible time series

xts + C

- Moving [.xts to C dramatically decreased subsetting costs
- Highest cost basic operation in R was merge. Prime C candidate
- Implemented optimized sort-merge-join in C with custom algorithm
- Additional C based routines followed...

xts now has 3000+ lines of C

xts: extensible time series

...in development

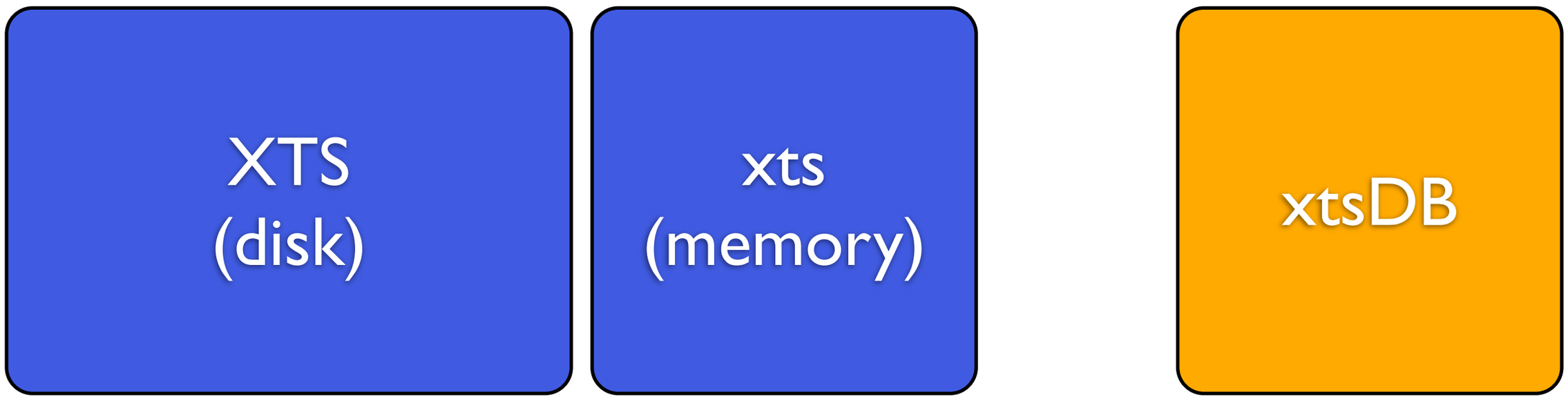
xts: extensible time series

Binary .xd files

Representation of xts objects on disk

Seekable for disk-based subsetting

Future time-series database structure



Parallel processing

period.apply

runSum, runCov, runSD, etc.

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Multiple index support

index *lists*

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runSum, runCov, runSD, etc.

Multiple index support

index *lists*

Tighter zoo integration

Backport C code into zoo


AAPL
[2008–12–01/2009–03–23]
105
100
95
90
85
80
Dec 01 2008
Dec 15 2008
Dec 29 2008
Jan 12 2009
Jan 26 2009
Feb 09 2009
Feb 23 2009
Mar 09 2009
Mar 23 2009

quantmod

quantmod

quantmod was envisioned to be a rapid prototyping environment in R to facilitate quantitative modeling, testing, and trading

quantmod

Data. Visualization. Modeling.

quantmod

Data. Visualization. Modeling.

Trading requires lots of different types of data, from many different sources. quantmod aims to hide the details of the data source, to make *using* data a priority

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`getSymbols`

quantmod

Data. Visualization. Modeling.

`getSymbols`

csv	Rdata	MySQL
SQLite	google	yahoo
Interactive Brokers	FRED	oanda

Data. Visualization. Modeling.

`getSymbols`

getSymbols is the top level function that dispatches to custom methods based on user direction

setSymbolLookup
getSymbolLookup
saveSymbolLookup
loadSymbolLookup

Data. Visualization. Modeling.

`getSymbols`

getSymbols behave like base::load by assigning objects into the user's workspace (.GlobalEnv)

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`getSymbols`

getSymbols behave like base::load by assigning objects into the user's workspace (.GlobalEnv)

Rationale: when dealing with potentially dozens of symbols interactively, it is redundant to have to manually assign each. Also facilitates multiple requests.

quantmod

Data. Visualization. Modeling.

`getSymbols`

getSymbols("AAPL")
getSymbols("AAPL;SBUX")
getSymbols("USD/EUR",src= "oanda")

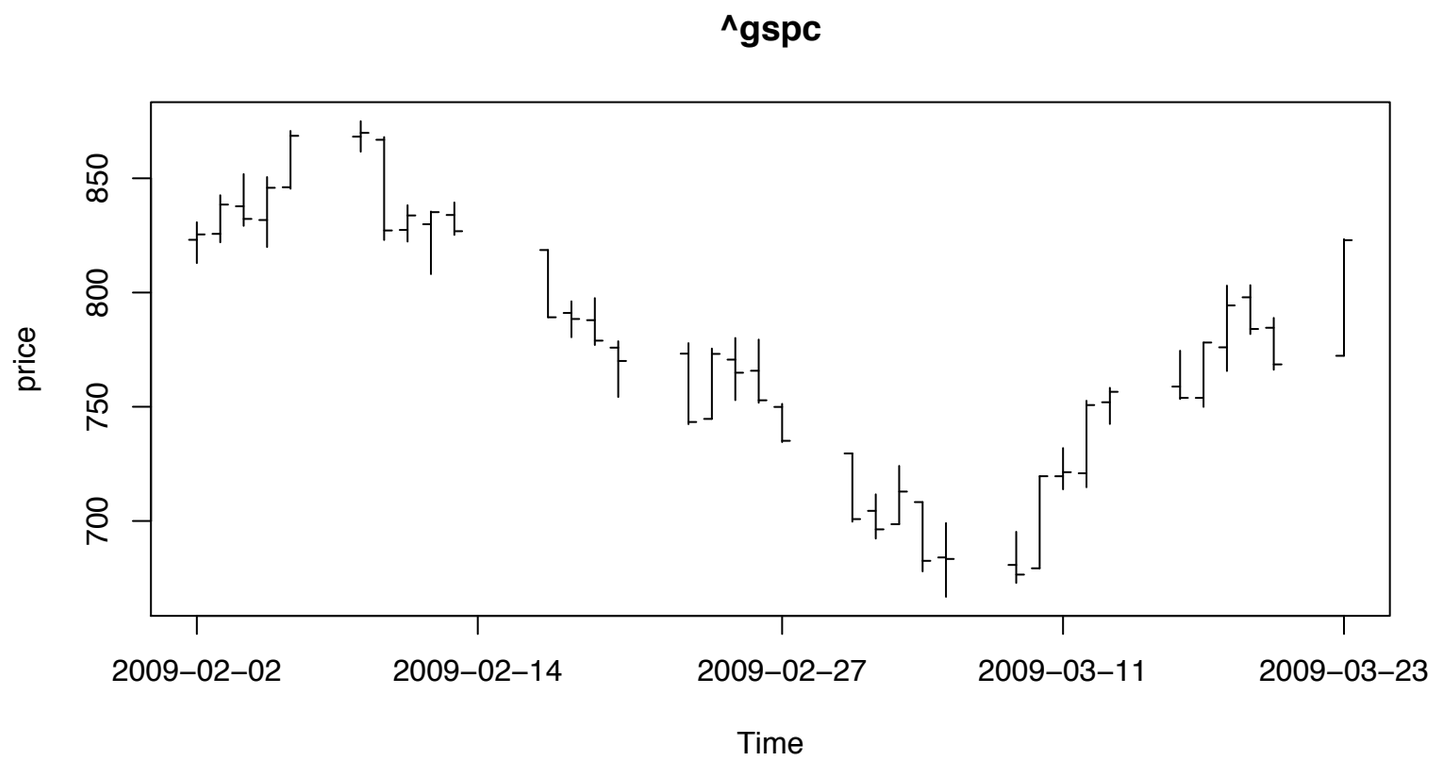
quantmod

Data. Visualization. Modeling.

Interactive, highly customizable financial charting *in* R

quantmod

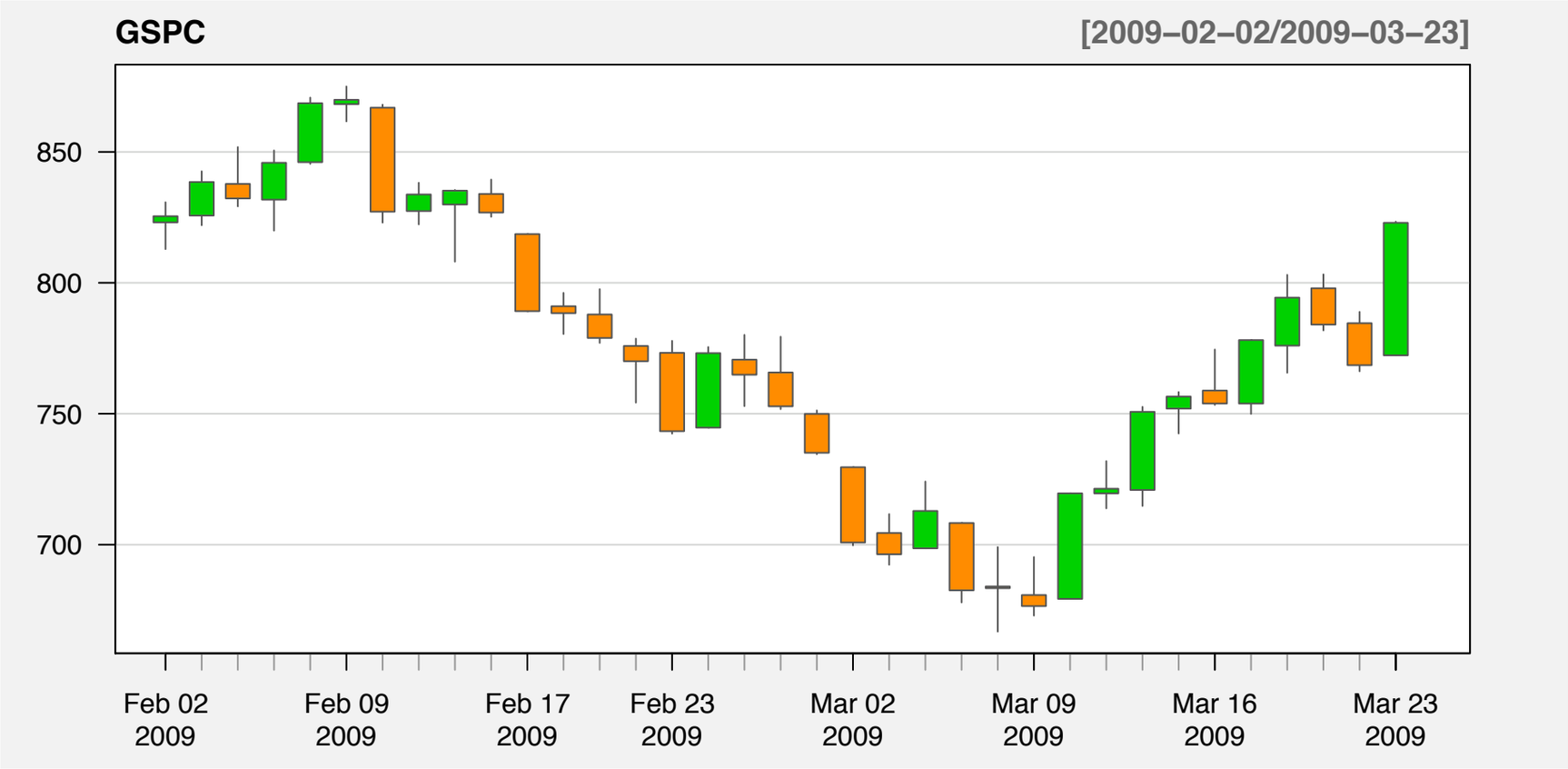
Data. Visualization. Modeling.



Basic OHLC chart from tseries

quantmod

Data. Visualization. Modeling.




```
candleChart(GSPC, subset='200902/', theme='white', TA=NULL)
```

Data. Visualization. Modeling.

Requirements

- Fast rendering (base plotting tools)
- Interactive and scriptable
- Work with all timeseries classes
- Minimal commands
- Highly customizable
- Full technical analysis support (via TTR)

Data. Visualization. Modeling.

The Basics


```
> chartSeries(IBM)
```

Data. Visualization. Modeling.

The Basics


```
> addBBands()
```

quantmod

Data. Visualization. Modeling.

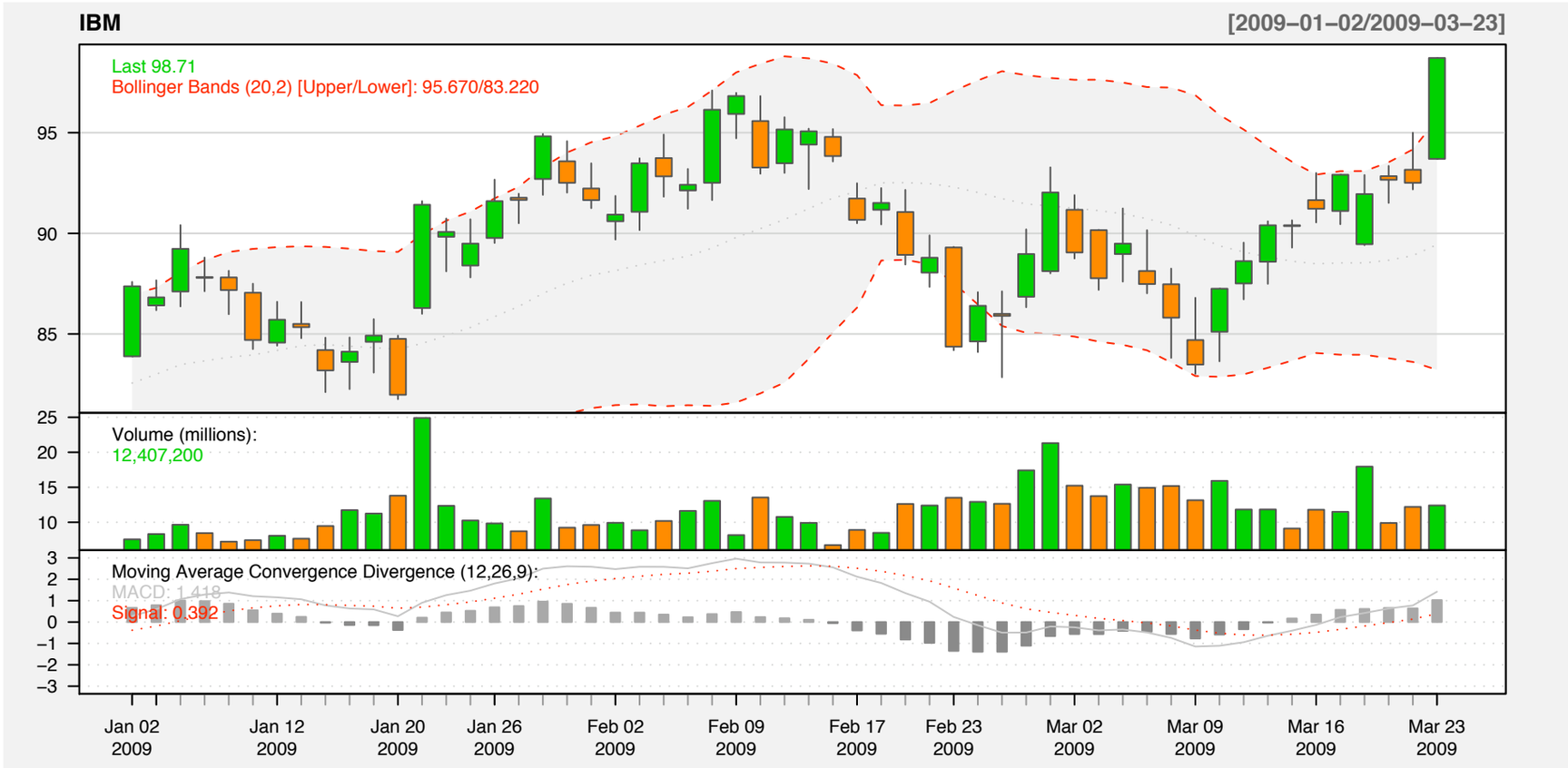
The Basics


```
> addMACD(32,50,12)
```

quantmod

Data. Visualization. Modeling.

The Basics




```
> reChart(subset= “2009”,theme= “white”, type= “candles”)
```

quantmod

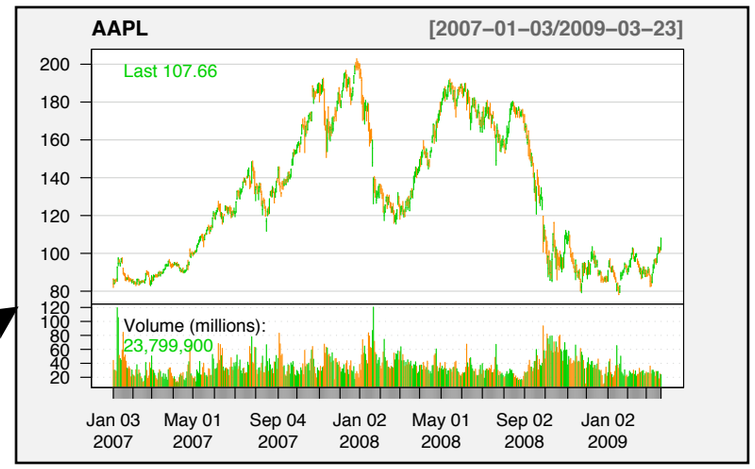
Data. Visualization. Modeling.

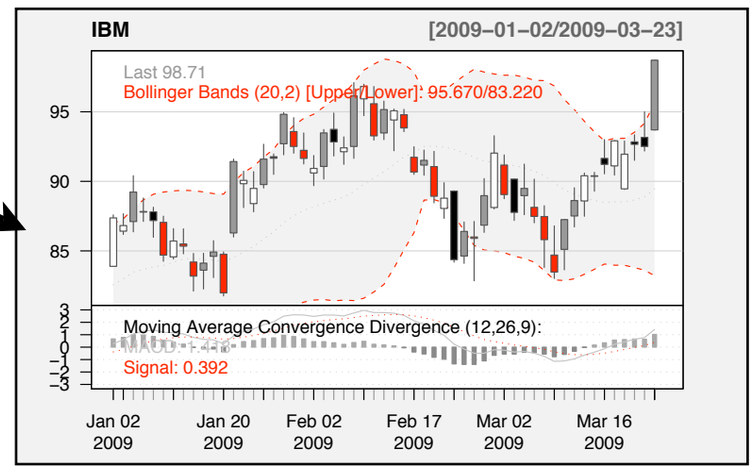
Inside chartSeries

chartSeries

addTA → chobTA

chob
(chart object)





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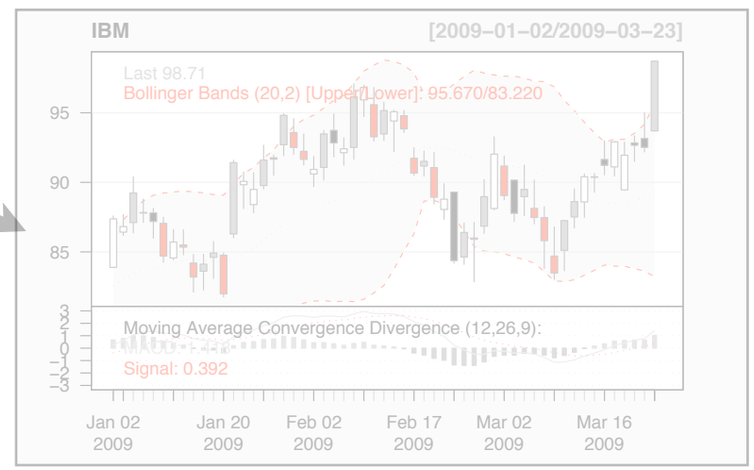

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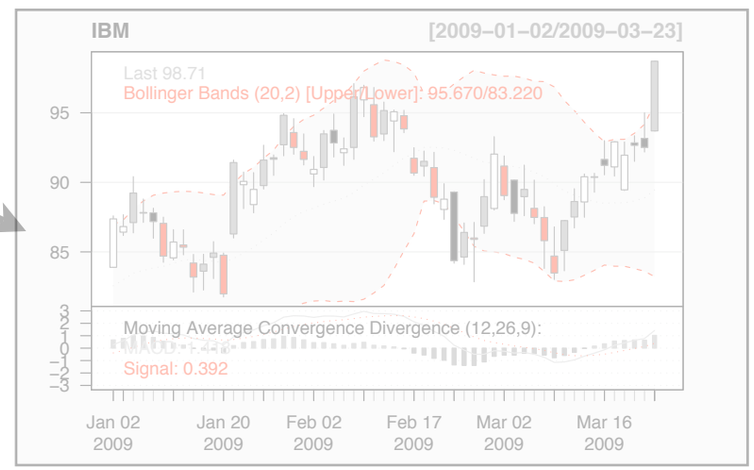
chob
(chart object)



quantmod

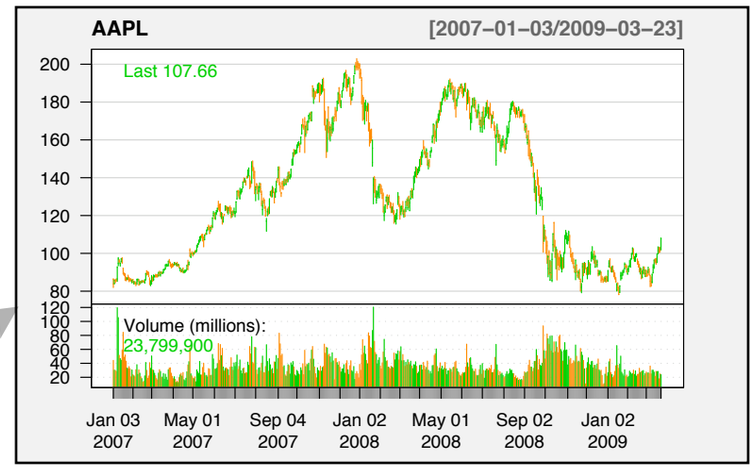
Data. Visualization. Modeling.

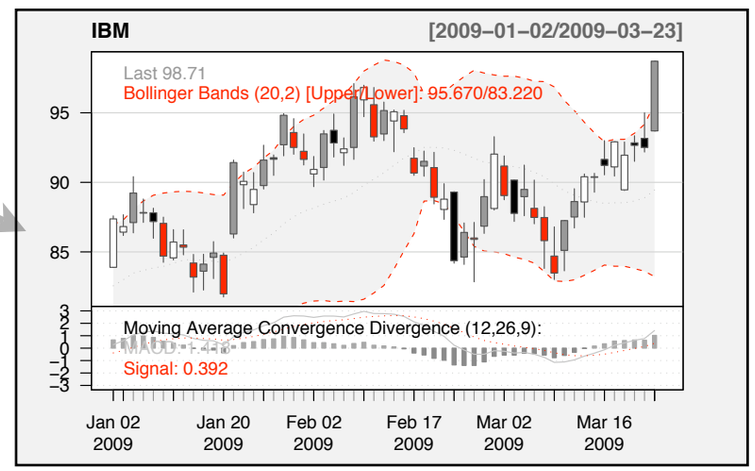
Inside chartSeries

chartSeries

addTA → chobTA

chob
(chart object)





Drawn by chartSeries.chob

Data. Visualization. Modeling.

Extending chartSeries

quantmod

Data. Visualization. Modeling.

GMMA
Guppy Multiple Moving Average
(with newTA)

quantmod

Data. Visualization. Modeling.

```
> # create a function that returns our GMMA
> GMMA <- function(x) {
+     fastMA   <- c(3,5,8,10,12,15)
+     slowMA  <- c(30,35,40,45,50,60)
+     x <- sapply(c(fastMA,slowMA),
+                 function(xx) EMA(x,xx))
+     return(x)
+ }
>
```

quantmod

Data. Visualization. Modeling.

```
> # create a function that returns our GMMA
> GMMA <- function(x) {
+     fastMA   <- c(3,5,8,10,12,15)
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+     x <- sapply(c(fastMA,slowMA),
+                 function(xx) EMA(x,xx))
+     return(x)
+ }
>
```

```
> # create an addGuppy function with newTA
> addGuppy <- newTA(FUN=GMMA,
+                   preFUN=Cl,
+                   col=c(rep(3,6),
+                         rep("#333333",6)),
+                   legend="GMMA")
> class(addGuppy)
[1] "function"
```

Data. Visualization. Modeling.

```
> # create a function that returns our GMMA
> GMMA <- function(x) {
+     fastMA   <- c(3,5,8,10,12,15)
+     slowMA  <- c(30,35,40,45,50,60)
+     x <- sapply(c(fastMA,slowMA),
+                 function(xx) EMA(x,xx))
+     return(x)
+ }
```

candleChart(AAPL); addGuppy()

```
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> class(addGuppy)
[1] "function"
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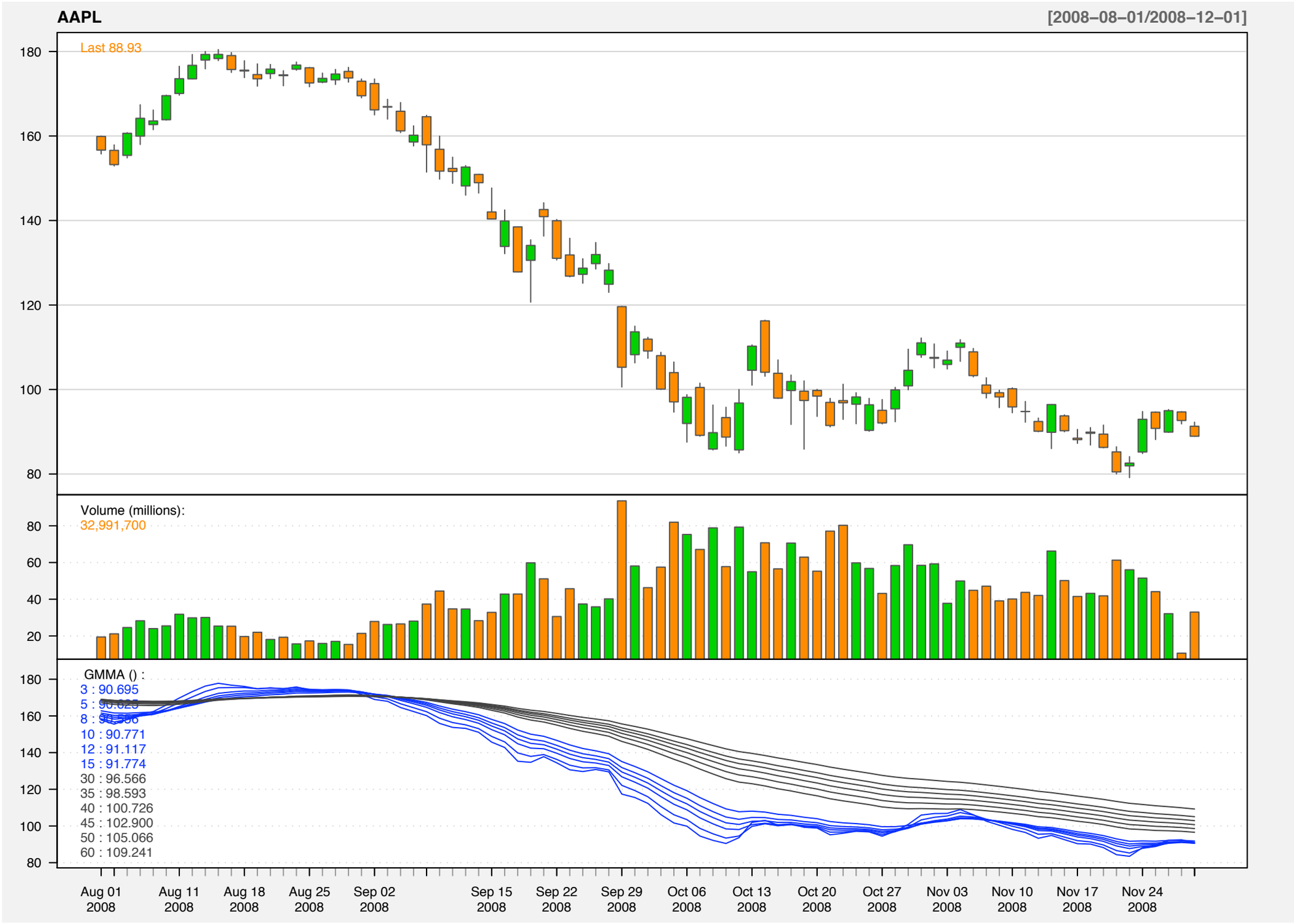
quantmod

Data. Visualization. Modeling.

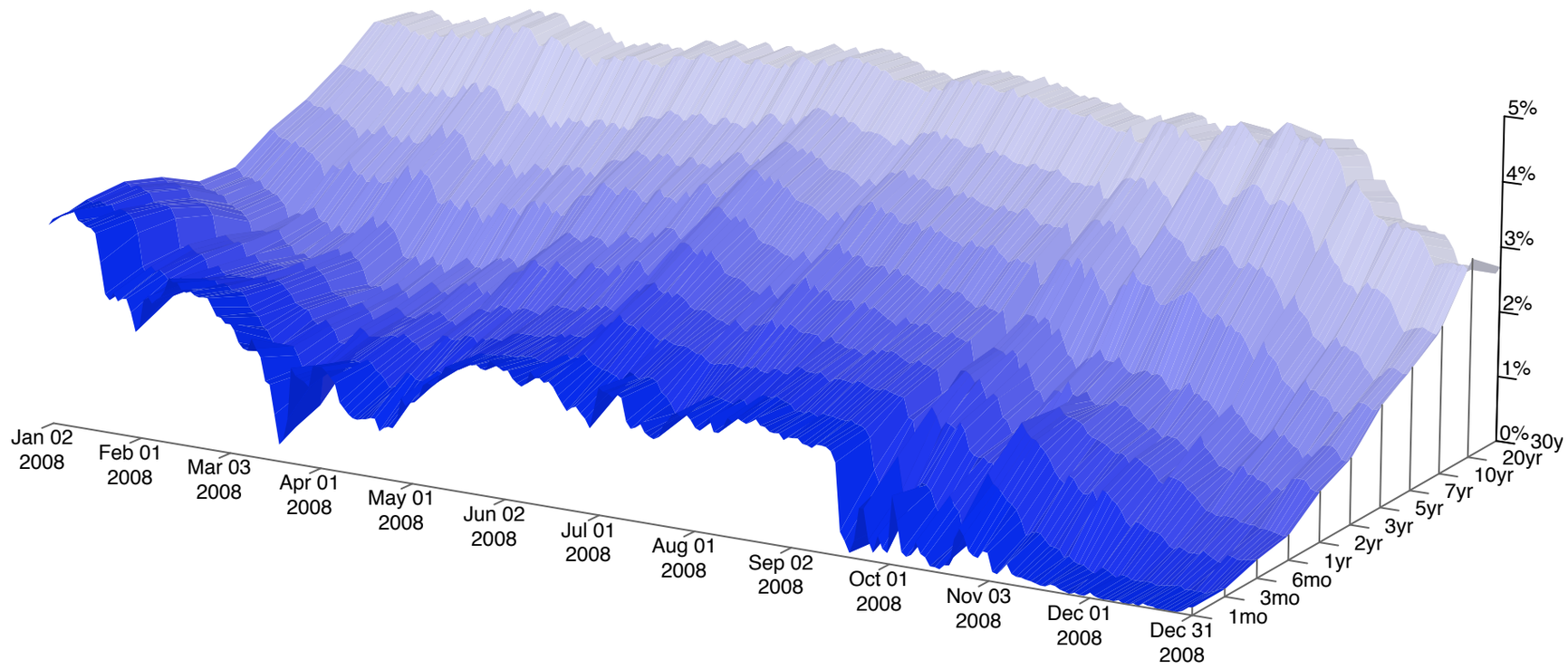


quantmod

Data. Visualization. Modeling.

chartSeries3d

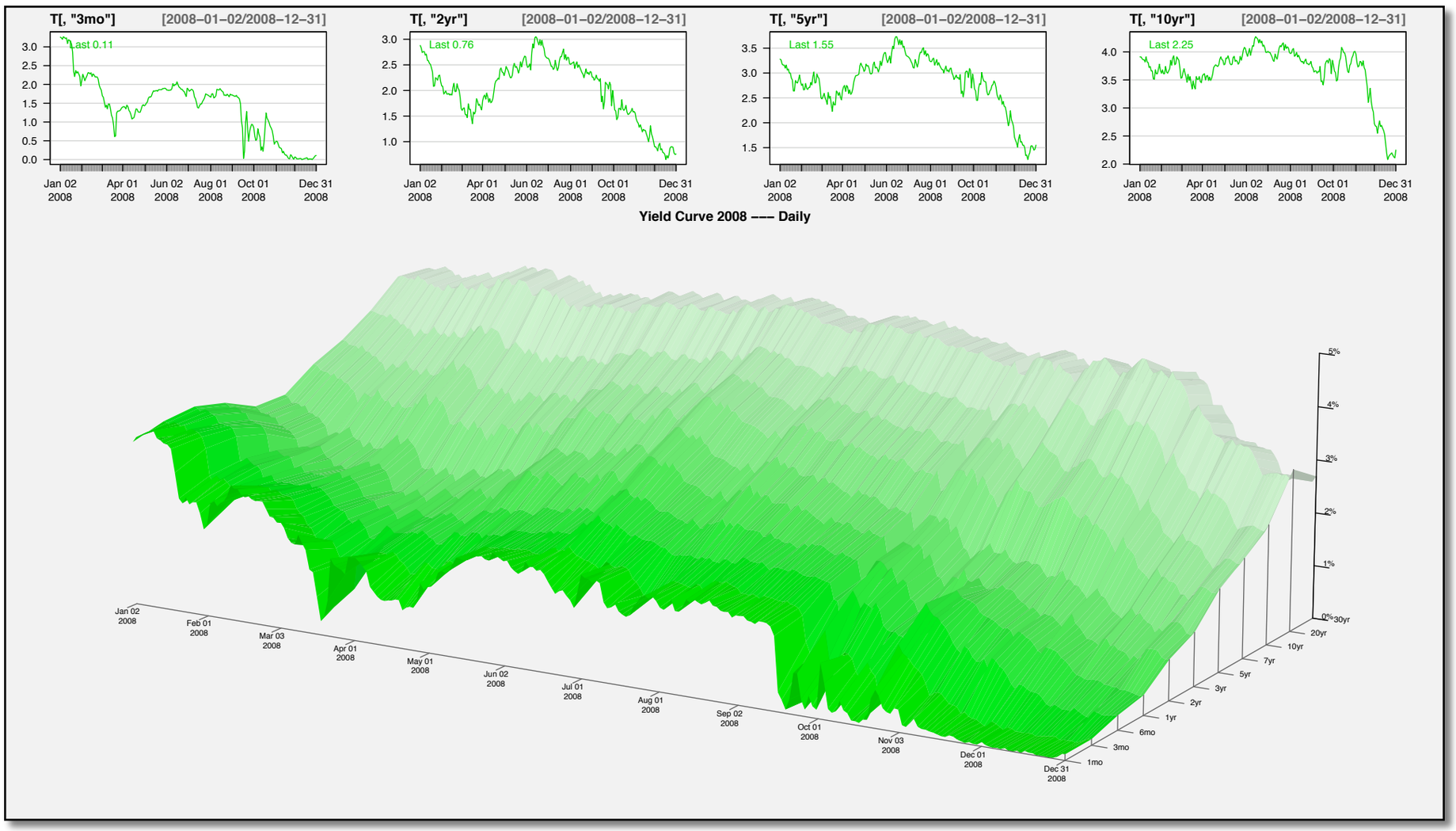
Yield Curve 2008 ––– Daily



quantmod

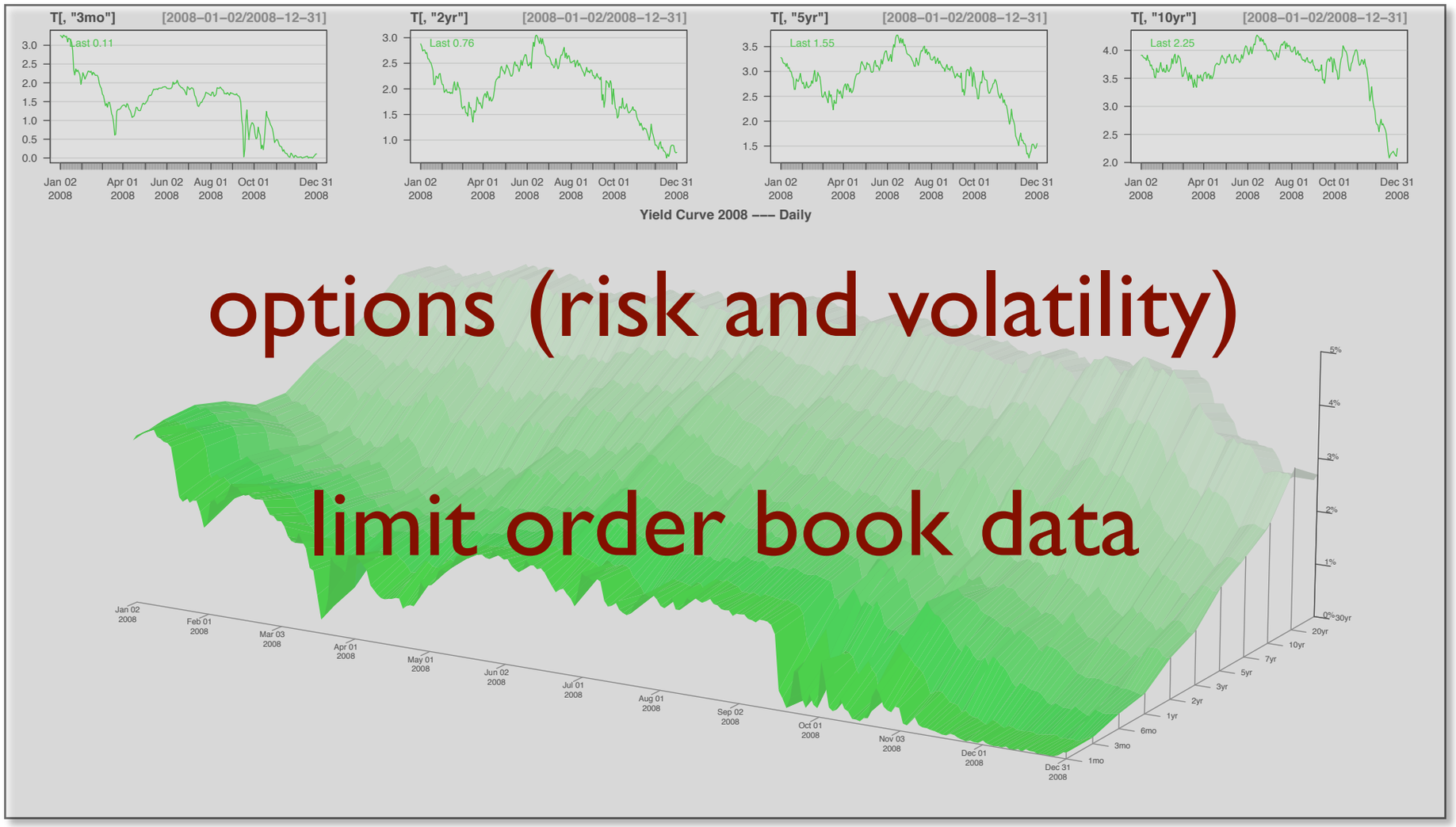
Data. Visualization. Modeling.

chartSeries + chartSeries3d



quantmod

Data. Visualization. Modeling.



attachSymbols

New functionality to extend upon getSymbols

attachSymbols

New functionality to extend upon getSymbols

Create a demand based database system using getSymbols that allows for implicit loading of an entire universe of symbols

attachSymbols

Example: All US Equity symbols on demand.

```
> search()
 [1] ".GlobalEnv"        "package:quantmod"  "package:Defaults"
 [4] "package:xts"       "package:zoo"       "package:stats"
 [7] "package:graphics"  "package:grDevices" "package:utils"
[10] "package:datasets"  "package:methods"   "Autoloads"
[13] "package:base"
```

quantmod

attachSymbols

Example: All US Equity symbols on demand.

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 [1] ".GlobalEnv"        "package:quantmod"  "package:Defaults"
 [4] "package:xts"       "package:zoo"       "package:stats"
 [7] "package:graphics"  "package:grDevices" "package:utils"
[10] "package:datasets"  "package:methods"   "Autoloads"
[13] "package:base"

> attachSymbols(DB=DDB_Yahoo(), pos=2, prefix="E.")
```

Contains symbols and method

attachSymbols

Example: All US Equity symbols on demand.

```
> search()
 [1] ".GlobalEnv"        "package:quantmod"  "package:Defaults"
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 [7] "package:graphics"  "package:grDevices" "package:utils"
[10] "package:datasets"  "package:methods"   "Autoloads"
[13] "package:base"

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attachSymbols

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 [4] "package:Defaults"  "package:xts"       "package:zoo"
 [7] "package:stats"     "package:graphics"  "package:grDevices"
[10] "package:utils"     "package:datasets"  "package:methods"
[13] "Autoloads"         "package:base"

> str(ls("DDB:Yahoo"))
 chr [1:7406] "E.A" "E.AA" "E.AAC" "E.AACC" "E.AAI" "E.AAII" ...
```

attachSymbols

Example: All US Equity symbols on demand.

```
> search()
 [1] ".GlobalEnv"        "package:quantmod"  "package:Defaults"
 [4] "package:xts"       "package:zoo"       "package:stats"
 [7] "package:graphics"  "package:grDevices" "package:utils"
[10] "package:datasets"  "package:methods"   "Autoloads"
[13] "package:base"

> getSymbols("^GSPC")
[1] "GSPC"

> getSymbols("^DJI")
[1] "DJI"

> getSymbols("^IXIC")
[1] "IXIC"

> getSymbols("^TNX")
[1] "TNX"

> getSymbols("^VIX")
[1] "VIX"

> getSymbols("^RUT")
[1] "RUT"

> search()
 [1] ".GlobalEnv"        "DDB:Yahoo"         "package:quantmod"
 [4] "package:Defaults"  "package:xts"       "package:zoo"
 [7] "package:stats"     "package:graphics"  "package:grDevices"
[10] "package:utils"     "package:datasets"  "package:methods"
[13] "Autoloads"         "package:base"

> str(ls("DDB:Yahoo"))
 chr [1:7406] "E.A" "E.AA" "E.AAC" "E.AACC" "E.AAI" "E.AAII" ...
```

7406 symbols are available

attachSymbols

Example: All US Equity symbols on demand.

```
> str(E.A)
An 'xts' object from 2007-01-03 to 2009-03-23 containing:
  Data: num [1:559, 1:6] 35 34.3 34.3 34 34.1 ...
 - attr(*, "dimnames")=List of 2
  ..$ : NULL
  ..$ : chr [1:6] "A.Open" "A.High" "A.Low" "A.Close" ...
  Indexed by objects of class: [POSIXt,POSIXct] TZ: America/
Chicago
  xts Attributes:
List of 2
 $ src    : chr "yahoo"
 $ updated: POSIXct[1:1], format: "2009-03-24 10:59:14"
```

attachSymbols

Example: All US Equity symbols on demand.

```
> str(E.A)
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  Data: num [1:559, 1:6] 35 34.3 34.3 34 34.1 ...
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  ..$ : NULL
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Chicago
  xts Attributes:
List of 2
 $ src    : chr "yahoo"
 $ updated: POSIXct[1:1], format: "2009-03-24 10:59:14"
```

First access loads data

attachSymbols

Example: All US Equity symbols on demand.

```
> system.time(E.AKAM)
   user  system elapsed
  0.032   0.004   0.267
```

download from Yahoo

attachSymbols

Example: All US Equity symbols on demand.

```
> system.time(E.AKAM)
   user  system elapsed
  0.032   0.004   0.267

> system.time(E.AKAM)
   user  system elapsed
      0       0       0
```

subsequent calls from cache

attachSymbols

Two Methods to Cache

Disk

after first access, objects are cached to disk.

makeActiveBinding

Memory

after first access objects remain in memory

delayedAssign

attachSymbols

Custom DDB methods

example: DDB:Yahoo

```
> DDB_Yahoo()
> # creates DDB of all US Equity Symbols
```

attachSymbols

Custom DDB methods

example: DDB:Yahoo

```
> attachSymbols()
> # “binds” symbols to functions to load/reload
```

attachSymbols

Custom DDB methods

example: DDB:Yahoo

All symbols are attached to new environment and accessible on demand.

Future Work

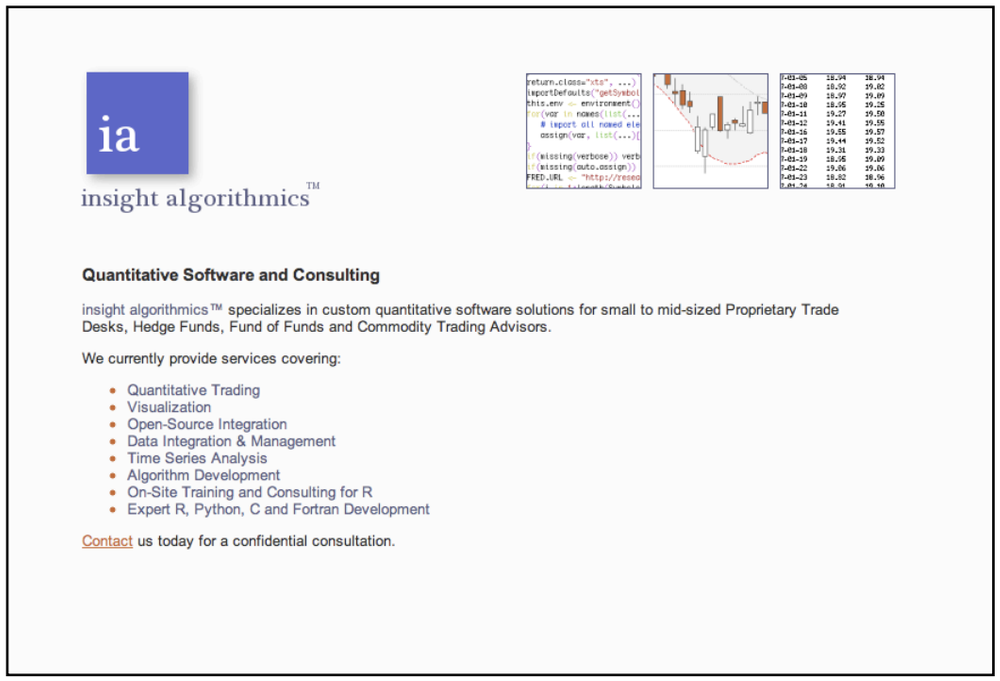
Integration of trading/testing with blotter package

More data methods, easier to extend

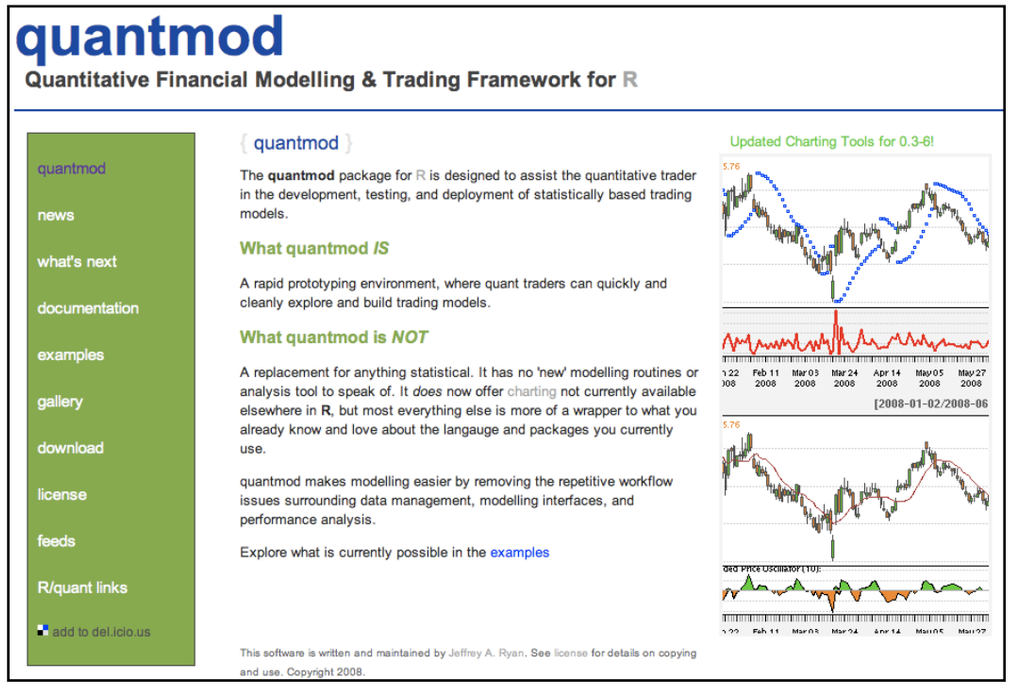
specifyModel - buildModel - tradeModel work

More Information

www.insightalgo.com



www.quantmod.com



Presented by Jeffrey A. Ryan jeffrey.ryan@insightalgo.com

www.quantmod.com/Vienna2009