Plotting 'timeSeries' Objects

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1 Introduction

The Rmetrics `timeDate` and `timeSeries` packages are workhorses to deal with chronological objects. Since their inception 2009 under their original names `fCalendar` and `fSeries` they have been only slightly modified. With version R 3.1. we have essentially improved the `plot` function, but we also took care that the functionality is almost upward compatible.

In this vignette we show how to work with the recently updated S4 generic plot function `plot`. The function is written to display Rmetrics S4 `timeSeries` objects. The basic functionality of the `plot` function is to display single and multiple views on univariae and multivariate `timeSeries` objects. The function `plot.ts` from R's base environment, which displays basic `ts` time series objects, served as a model for our design of the generic S4 `plot` function for `timeSeries` objects. Similarily, `plot.ts` can be considered as the prototype for the S3 `plot.zoo` method. The `xts` plot function was build to display univariate `xts` time series objects which inherit from `zoo`'s objects for ordered time series objects.

The generic S4 time series plotting function can dispay *univariate* and *multivariate* time series in *single* and *multiple* frames. The plots can be tailored with respect to several viewing components: colors (col), line types (lty), plot symbols (pch), line widths (lwd), symbol sizes (cex), axis layout (pretty, chic, tailored), minor tick mark appearence, font styles and font sizes, frame positioning (mar, oma), as well as tailored panel functions (panel).

General Plot Settings and Design Apects:

Plot Type: Univariate time series are displayed by default in `plot.type="single"` frames, multivariate time series are displayed by default in `plot.type="multiple"` frames. The default line style for a plot is `type ="l"` is drawn with "lines".

Time Axis Layout: For the time axis layout the function `pretty` determines in an automative way the `at="pretty"` positions of the ticks. The `format="auto"` is extracted from the time stamps of the time series object or can be overwritten by the user with a POSIX format string. Alternatively, one can select `"chic"` to generate time axis styles. We called this method "chic" to give reference to the underlying function `axTicksByTime` from the Chicago `xts` package which generates tick positions and axis labels. Furthermore, a "tailored" method can be applied which allows for fully arbitrary user defined positions and formatted labels. Minor ticks can be added in several fashions.

Annotations: The annotations of the plots are reduced to the y-label. These are taken by default from the column names of the time series object. This gives the

user the freedom to have full control about his views how the plot should be look like. Note, multivariate time series in single plots show the string `"Values"` as label on the y-axis. Main title, sub title, and the x-label on the time axis are not shown by default. We prefer and recommend to add these decorations calling the function `title`. This allows also much more flexibility compared to passing the arguments through the plot functions. All default annotations (including the y-label) can be suppressed setting the plot function argument to `ann=FALSE`. The argument `axes=FALSE` suppresses to draw both axes on the plot frame.

Decorations: There are several options to decorate the plot: These include colors (col), plotting symbols (pch), scaling factor of plotting characters and symbols (cex), line types (lty), and lindwidths (lwd). Note, all these parameters may be vectors of the same length as the number of time series, so that each series can be addressed to its own individual style, color, and size. A grid and the plot frame (box) can be added or suppresse specifying the arguments `grid` and `frame.plot` in the argument list of the `plot` function.

Panel Function: In the case of multiple plots the plot frames, are also called *panels*. By default in each panel the appropriate curve is drawn calling R's `lines` function `panel=lines`. This function can be replaced by a user defined function. This offers a wide range of new views on your time series. So for example yo can show zero or any other reference lines on the panels, or you can add rugs to (return) charts, or you can add for an example an EMA indicator (or any other kind of indicator) to curves shown in individual panels.

Example "timeSeries" Objects: To demonstrate the wide range of options to dispaly S4 `timeSeries` objects, we use the the daily index values from the Swiss Pension Fund Benchmark *LPP2005*. The time series is part of the `timeSeries` package. For this we have introduced some abbreviations:

```
> Sys.setlocale("LC_ALL", "C")
```

```
[1] "LC_CTYPE=C;LC_NUMERIC=C;LC_TIME=C;LC_COLLATE=C;LC_MONETARY=C;LC_MESSAGES=en_US.UTF-8;
```

```
> require(timeSeries)
> require(xts)
> require(PerformanceAnalytics)
> require(fTrading)
> tS1 <- 100 * cumulated(LPP2005REC[, 1])     # SBI (univariate)
> tS2 <- 100 * cumulated(LPP2005REC[, 1:2])   # SBI & SPI (bivariate)
> tS3 <- 100 * cumulated(LPP2005REC[, 1:3])   # SBI, SPI, SWIIT (Swiss Market)
> tS6 <- 100 * cumulated(LPP2005REC[, 1:6])   # Swiss and Foreign Market Indexes
```

2 Standard Time Series Plots

The `plot` function from the `timeSeries` package allows for five different views on standard plot layouts. These include

- Univeriate single plots
- Multivariate single plots
- One column multiple plots
- Two column multiple plots
- Scatter plots

The only argument we have to set is the `plot.type` parameter to determine the layout of the plot. The default value is `"multiple"`, and the alternative value is `"single"`. The arguments can be abbreviated as `"m"` or `"s"`, respectively.

Univariate Single Plots were designed to plot univariate `timeSeries` objects in one single graph frame. Nothing then the `timeSeries` object has to be specified, the `plot.type` is forced to `"s"`.

Multivariate Single Plots will be used when a set of multivariate `timeSeries` objects should be drawn in one common data frame. For this argument the vlue `plot.type="s"` has to be specified.

One Column Multiple Plots display multivariate `timeSeries` objects, such that each series is plotted in its own frame. Up to four series, the frames are displayed in one column, for more series the frames are arranged in a two colum column display.

Two Column Multiple Plots handel the case of more than four `timeSeries` objects. Then the the series are displayed in two colums. In total, the number of rows is not restricted.

2.1 Univariate Single Plots

The most simple time series plot shows an univariate curve in a single plot. The axis is designed from "pretty" positions calculated from R's base function `pretty`. The labels are printed in the ISO 8601 standard date/time format.

```
> par(mfrow=c(1, 1))
> plot(tS1)
```

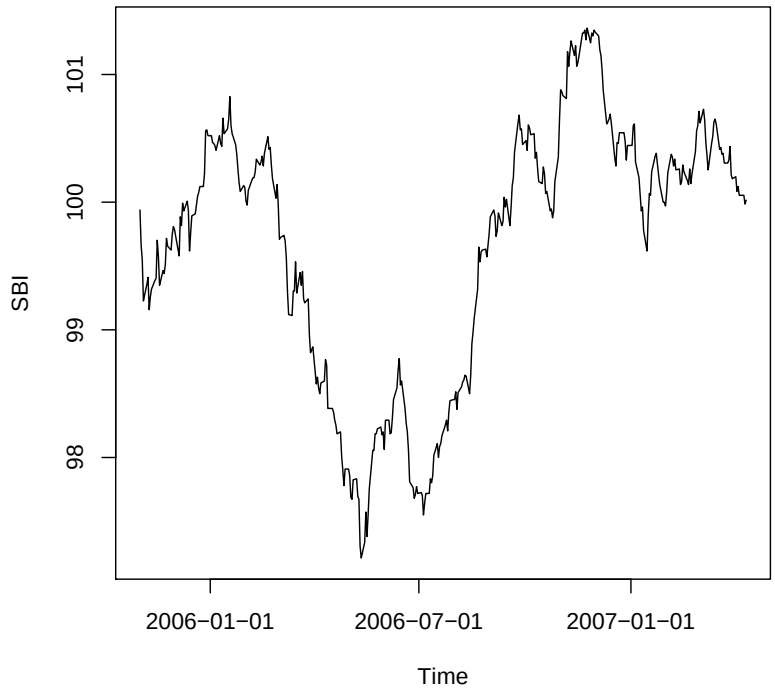


Figure 1: The chart shows an univariate time series (here the Swiss Bond Index) in a single frame. For all plot options default values have been chosen. You can decorate the plot, making it more conveniant to your needs, e.g.: change the color (col), add a main title and x-label calling the function `title`, or remove the grid lines setting the argument `grid=FALSE`. You can also design the minor tick marks, setting instead of the value `"auto"` oe of the following spreads: `"day"`, the default, `"week"`, or `"month"`.

Tow other plot function implementations for `xts` time series objects can be found in the contributesd R packages `xts` and `PerformanceAnalytics`. Let us compare how they generate plot positions and time label formats.

```
> require(PerformanceAnalytics)
> par(mfrow=c(3, 1))
> xts::plot.xts(as.xts(tS1))
> PerformanceAnalytics::chart.TimeSeries(as.xts(tS1))
> plot(tS1)
```

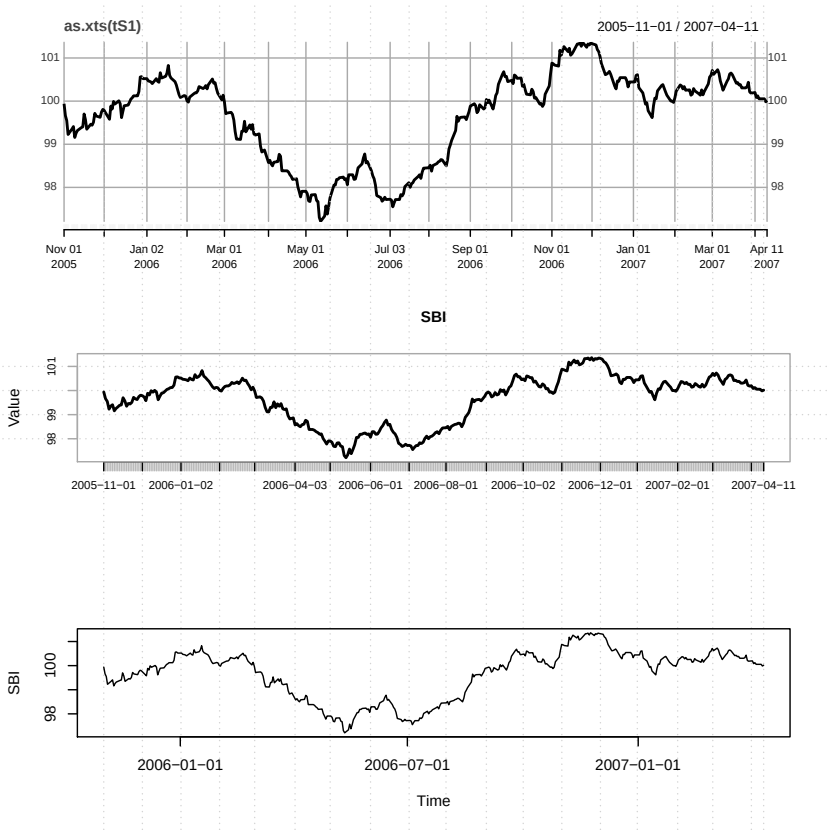


Figure 2: The group of the three charts shows an univariate time series in a single frame for the plot functions as implemented in the packages `xts`, `PerformanceAnalytics`, and `timeSeries`. For example in the case of daily time series records `xts` uses U.S. style labels whereas `PerformanceAnalytics` and `timeSeries` use ISO standard date labels `YYYY-mm-dd`. The plot decorations are those from default settings.

2.2 Multivariate Single Plots

Multivariate time series plots in a single panel are constructed by default in the way that the first curve is plotted calling the function `plot` and the remaining curves by calling the function `lines`.

```
> par(mfrow=c(1, 1))
> plot(tS3, plot.type="s")
```

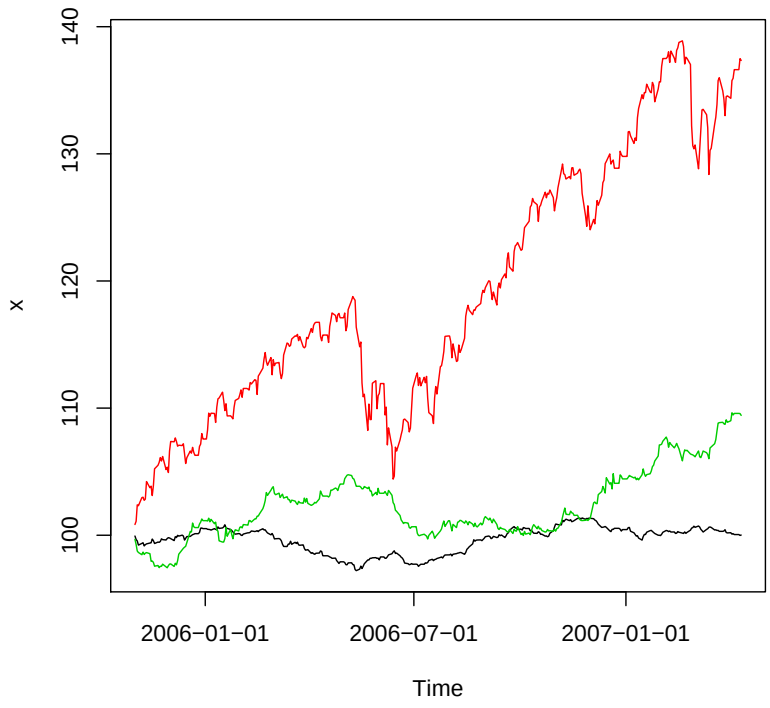


Figure 3: This chart shows a multivariate time series in a single frame. Note, we have to set the argument `plot.type="s"`. Again, for all plot options the default settings have been used. You can decorate the plot, making it more conveniant to your needs, e.g.: change the color vector (col), add a main title and x-label calling the function `title`, or remove grid lines setting the argument `grid=FALSE`. Note, to change the color settings you can set the argument `col=1:3` which would result in "black", "red", "green" for the three curves, or you can just set the colors by name, or selecting them from a color palette.

Now let us compare the plot function from the `timeSeries` package with the `chart.TimeSeries` plotting function from the `PerformanceAnalytics` function. (Note, the (xts) has no multivariate plot function implemented.)

```
> par(mfrow=c(2, 1))
> require(PerformanceAnalytics)
> PerformanceAnalytics::chart.TimeSeries(as.xts(tS3))
> plot(tS3, plot.type="s")
```

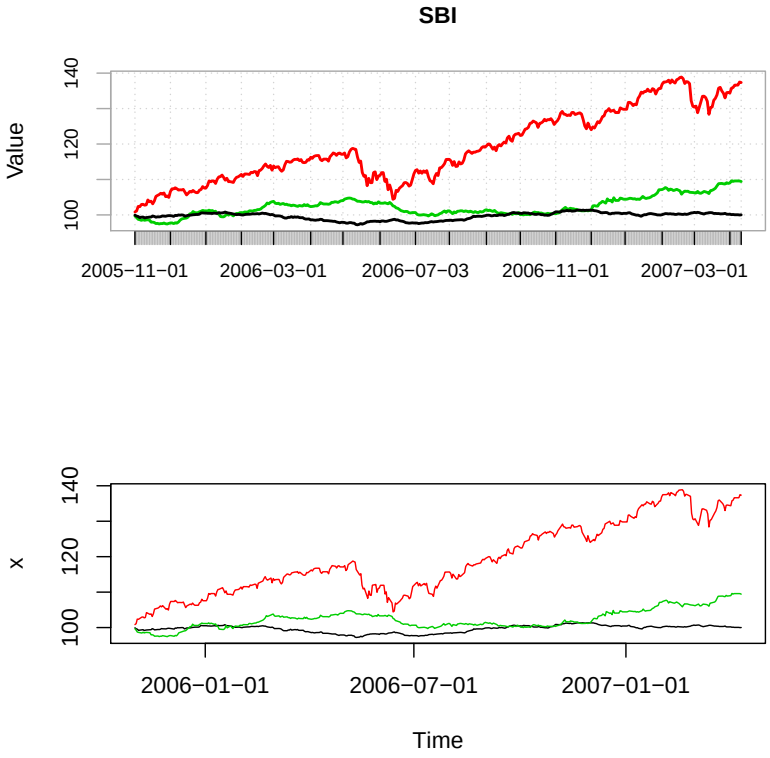


Figure 4: The two charts show a multivariate time series plotted in a single frame. We use for the plot the functions as implemented in the packages `PerformanceAnalytics`, and `timeSeries`.

2.3 Multiple Plots

Multiple plots enormously simplify the display of different curves in multiple panels. These are the ideal plots when it comes to the task to create a quick overview over several time series. Multiple plotting is exclusive to `timeSeries` objects, (xts) and `PerformanceAnalytics` offer no multiple plotting tool.

```
> par(mfrow=c(1, 1))
> plot(tS3, plot.type="m")
```

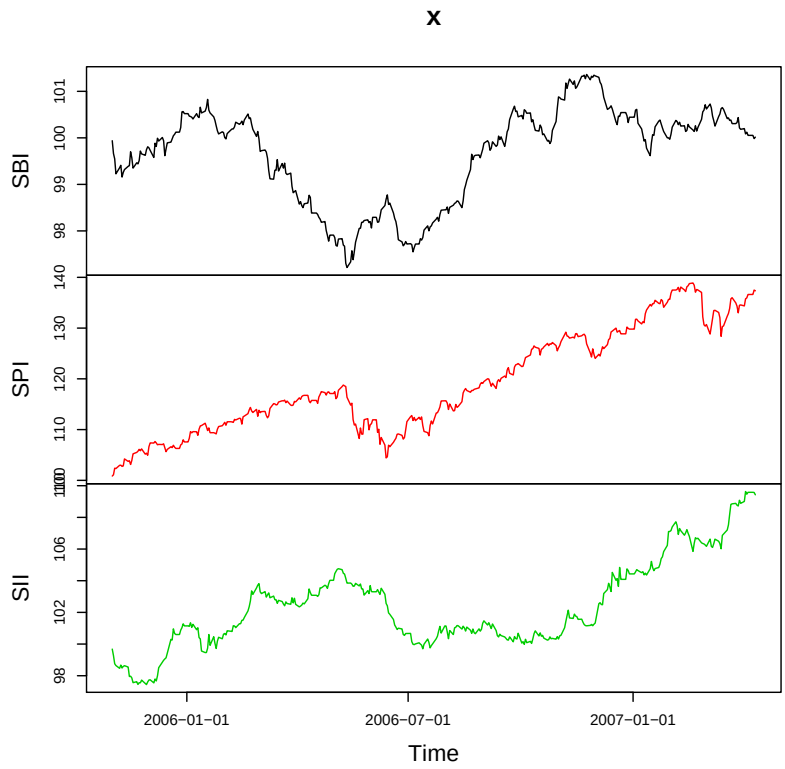


Figure 5: As long as we plot less than 4 time series in a multivariate frame, we get a one column layout. Annotations show by default only the y-labels which are taken from the colmun names of the time series to be drawn. Feel free to add main title, sub title, and x-label calling the function `title`

.

For more than four curves the frames of the plot design are arranged in two columns.

```
> par(mfrow=c(1, 1))
> plot(tS6, plot.type="m")
```

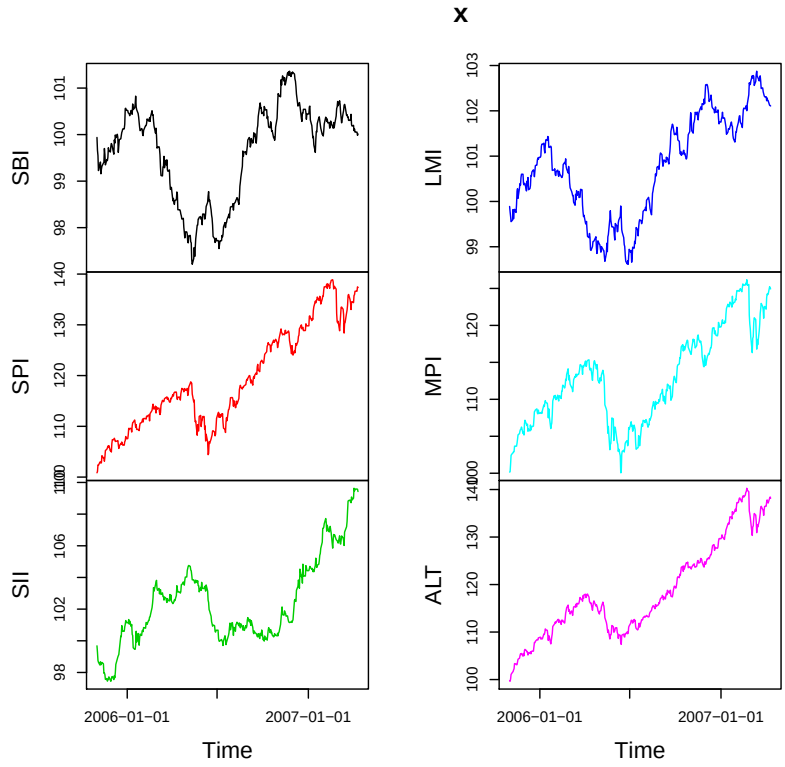


Figure 6: The graph shows the layout how it is created for six curves. There are two columns with three panels to the left and also three panels to the right. Note, it is easily possible to adapt the margin sizes and the gap between the two columns of plots calling the function `mar` and `oma`.

If you like a design with a small gap between the panel rows, you can modify the `mar` parameter to introduce a small gap, here with a width of 0.3. Feel free to modify it.

```
> par(mfrow=c(1, 1))
> plot(tS3, plot.type="m", mar=c(gap=0.3, 5.1, gap=0.3, 2.1))
```

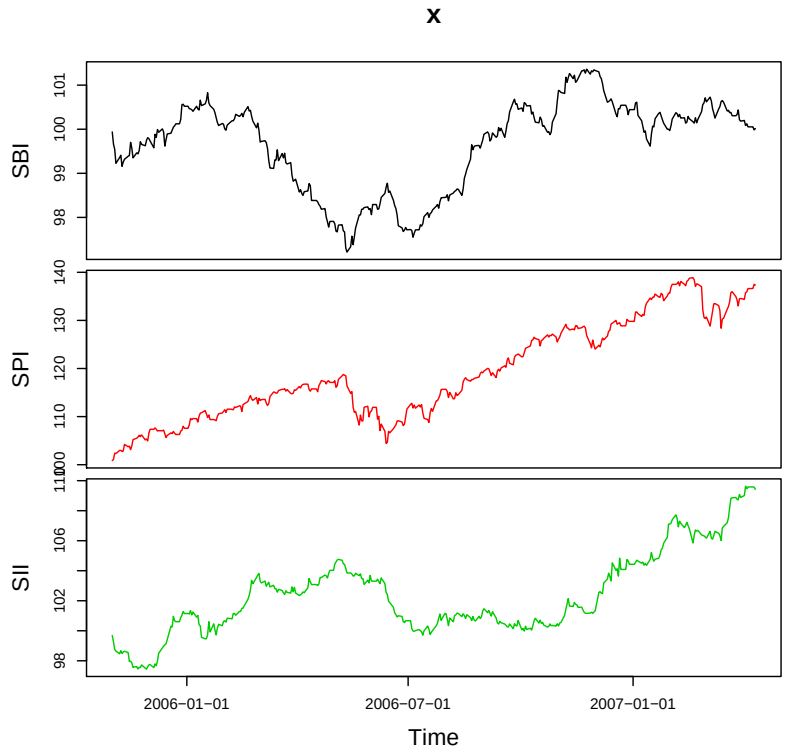


Figure 7: One can use in a multiple plot the `mar` parameter setting to create a small gap between the rows of the individual charts. This lets a plot look more elegant.

2.4 Combining Single Plots

You can also create your own multiple panel plots. Just combine single panels in an array of rows and columns using the parameter settings for `mfrow`, `mfcol`, and `mar`.

```
> par(mfrow=c(2, 1))
> par(mar = c(bottom=1.5, 5.1, top=4, 2.1))
> plot(tS2[, 1])
> par(mar = c(bottom=4, 5.1, top=1.5, 2.1))
> plot(tS2[, 2])
```

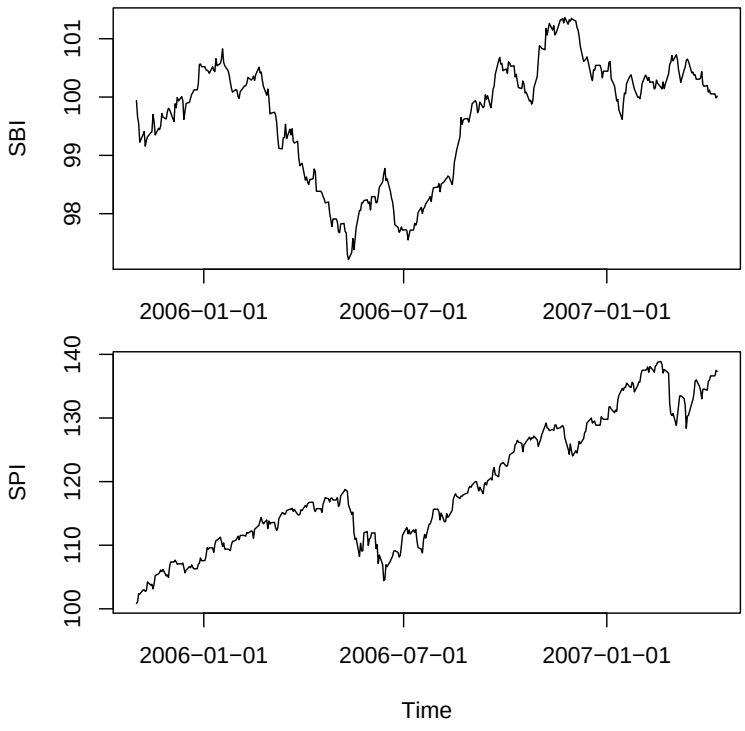


Figure 8: One can use in single plots the `mfrow` and `mar` parameter settings to place single plots either row by row or column by column. Here, `mfrow` and `mfcol` to the job. In this case a vector of the form `c(nr, nc)` draws subsequent figures in an nr-by-nc array on the device by columns (mfcol) or rows (mfrow), respectively.

2.5 Layout of Single Plots

There is another option in R to create panel layouts, not necessarilly in an rectangular array. Have a look to the help page of the function `layout`, her comes a simple example.

```
> nf <- layout(mat=matrix(c(1, 1, 2, 3), byrow = TRUE, nrow=2))
> par(mar = c(bottom=2, 5.1, top=3, 2.1))
> plot(tS3[, 1])
> par(mar = c(bottom=3, 5.1, top=2, 1.1))
> plot(tS3[, 2])
> par(mar = c(bottom=3, 4.1, top=2, 2.1))
> plot(tS3[, 3])
```

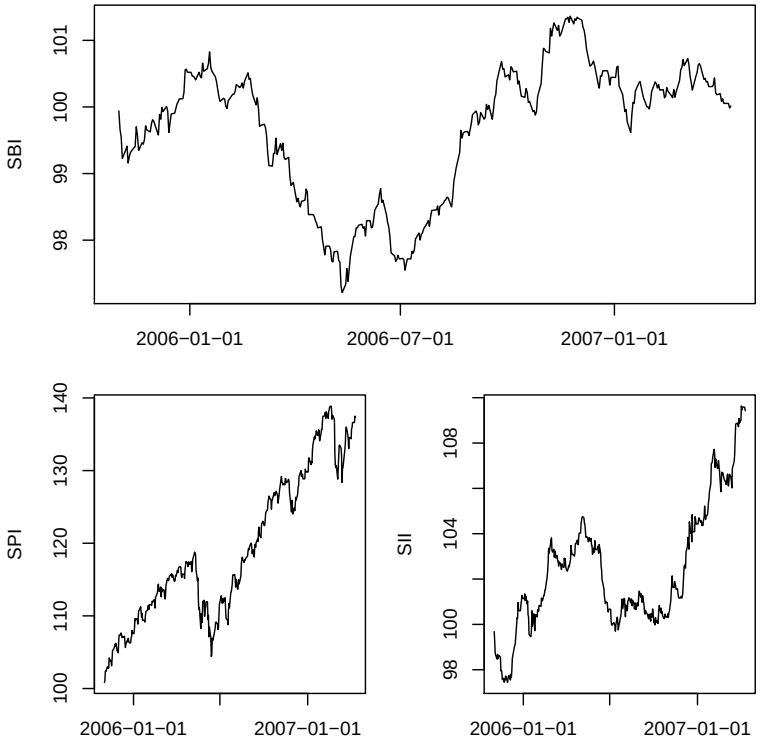


Figure 9: With the function `layout` you can devide the plot device in rows and columns expressed in matrix form defined by the argument `mat`.

In addition widths and heights of the layout can be different from row to row, and/or from column to column. The sizes are expressed by the arguments `widths` and `heights` of the function `layout`.

```
> nf <- layout(mat=matrix(c(1, 1, 2, 3), byrow=TRUE, nrow=2), heights=c(2.5,1))
> par(mar = c(bottom=2, 5.1, top=3, 2.1))
> plot(tS3[, 1])
> par(mar = c(bottom=3, 5.1, top=1.5, 1.1))
> plot(tS3[, 2])
> par(mar = c(bottom=3, 4.1, top=1.5, 2.1))
> plot(tS3[, 3])
```

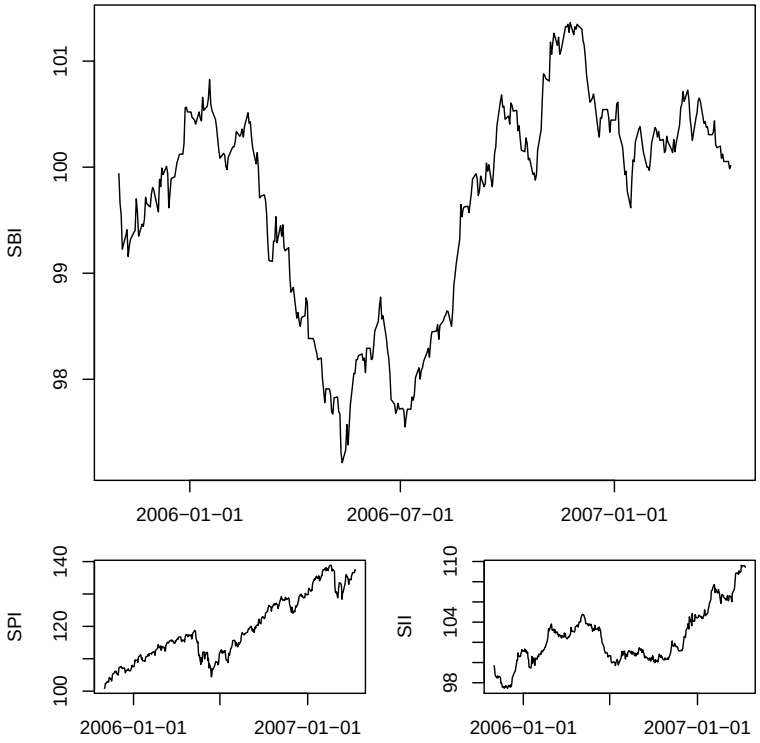


Figure 10: With the function `layout` one can also define the widths and heights of the columns and rows.

2.6 Bivariate Scatter Plots

For historical reasons, like in the function `plot.ts`, there is also the option to create an scatter plot from two univariaye time series. Since this is not a "true" time series plot, we will not go in further detail for this display.

```
> par(mfrow=c(1,1))
> plot(tS2[, 1], tS2[, 2])
```

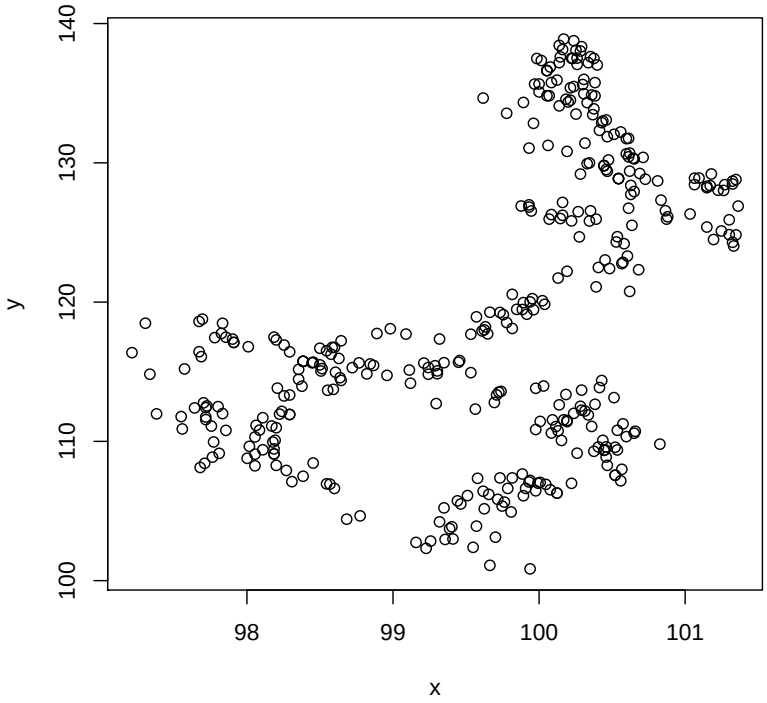


Figure 11: If (x) and (y) are univariate time series, then the plot function will display a scatter plot.

3 Time Axis Layout

The function `plot` comes with three options to design the time axis layout: `"pretty"`, `"chic"`, and <*tailored*> (note this not a string argument. <*tailored*> should just abbreviate that we have to input character strings of fully arbitray `at` positions. For the first two options the style of the axis annotation is generated in a fully automated way, whereas in the tailored case each tick on the axis to be user defined.

The *"pretty"* time axis layout is the default setting for the argument `at`. Internally the function `pretty` is used to compute a sequence of about `n+1` equally spaced round values which cover the range of the values in the time stamps `time(x)` of the series `x`. The values are chosen so that they are 1, 2 or 5 times a power of 10.

The *"chic"* time axis layout is the alternative setting for the argument `at`. Internally the function `axTicksByTime` from the package `xts` is used to compute the sequence of axis positions and the format labels.

The <*tailored*> time axis layout leaves it to the user to specify by himself the positions (at), the time label formatting (format), and the minor tick marks (minor.ticks).

3.1 Time Axis: ”pretty” or ”chic”?

Our plotting function comes with two axis-styles. The first is called `"pretty"`, which is the default style, and calculates positions from R's base function `pretty`. The other is called `"chic"` to remember its origin, arising from the ”Chicago” `xts` package.

```
> par(mfcol = c(2, 1))
> plot(tS1, at = "pretty")
> plot(tS1, at = "chic")
```

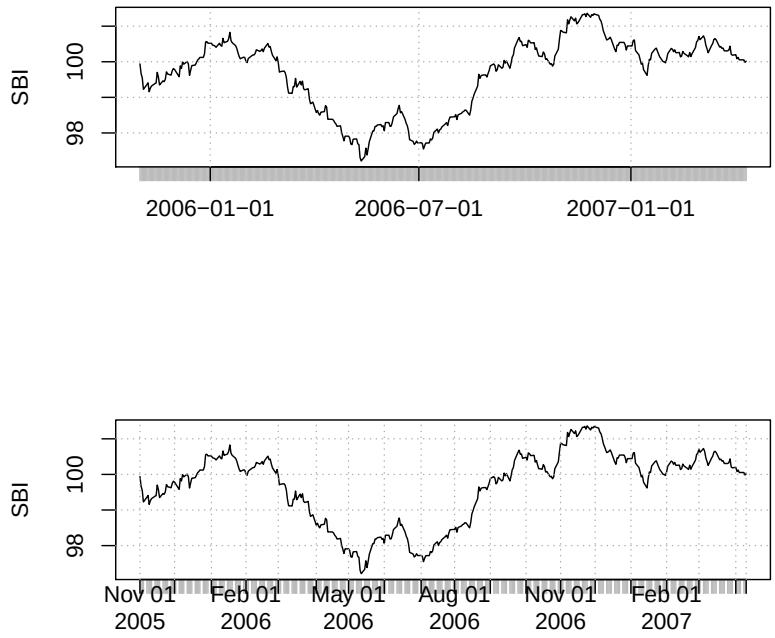


Figure 12: The graph shows the two flavours from the `at="pretty"` and the `"chic"` axis designs. The first style uses the function `pretty` from R's `base` environment to compute the positions for the major ticks. The second style uses the function `axTicksByTime` from the `xts` package to compute x-axis tick mark locations by time. In the upper graph the minor ticks are calendar days, whereas in the lower graph weekdays are drawn (therefore the small gaps between the minor ticks become visible). Note, the time series is in both cases an object of class `timeSeries`.

Now let us plot a multivariate 3-column time series in a single panel. Again we compare the outcome of the `"pretty"` and the `"chic"` axis style.

```
> par(mfcol=c(2, 1))
> plot(tS3, plot.type="s", at="pretty")
> plot(tS3, plot.type="s", at="chic")
```

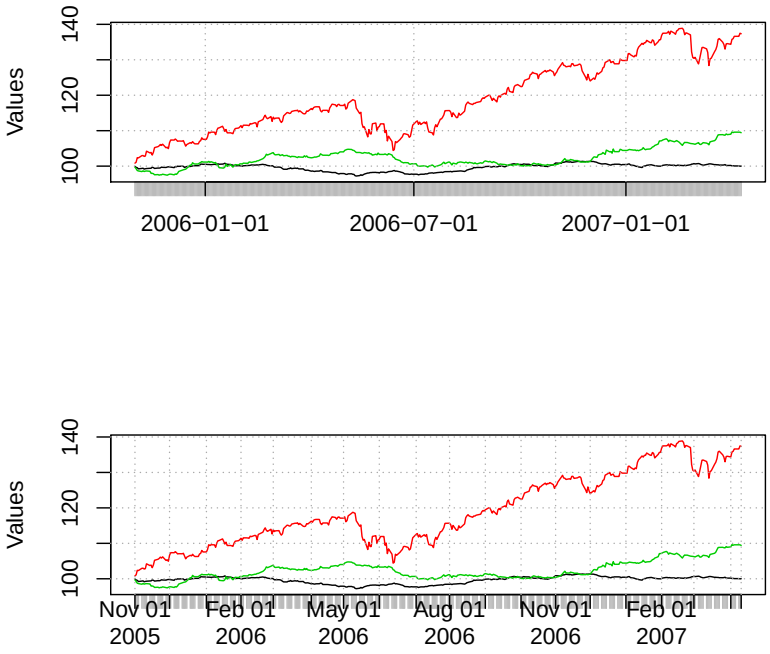


Figure 13: The only difference of this graph compared to the previous is the fact that we consider here a multivariate time series. Three curves are shown in a common plot. Note, when using the `"chic"` style, then the vertical gridlines are narrower compared to the `"pretty"` style.

3.2 Time Axis - Selecting Minor Tick Marks

The "pretty" style allows to draw the minor tick marks on different time scales. These are: "day", "week", and "month".

```
> par(mfrow=c(3, 1))
> plot(tS1, minor.ticks="day", at="pretty")
> plot(tS1, minor.ticks="week", at="pretty")
> plot(tS1, minor.ticks="month", at="pretty")
```

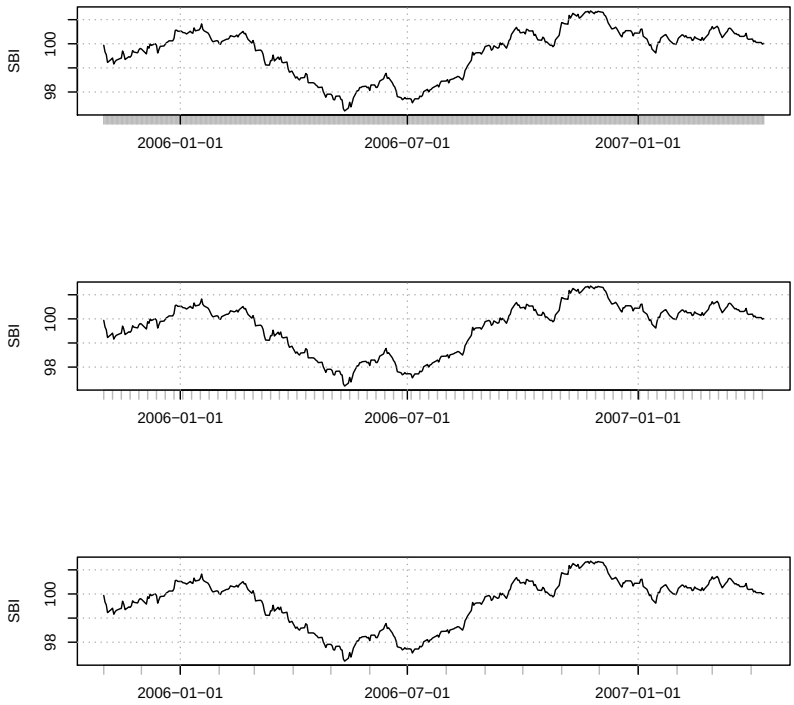


Figure 14: It is worth to note that a good selection of minor tick marks makes a plot much better readable.

3.3 Time Axis - One Column Multiple Plot Layout

In the multiple plot layout the axis are drawn along the same principles as they are drawn in the case of the single plot layout.

```
> par(mfrow=c(1, 1))
> plot(tS3, plot.type="m", at="pretty")
```

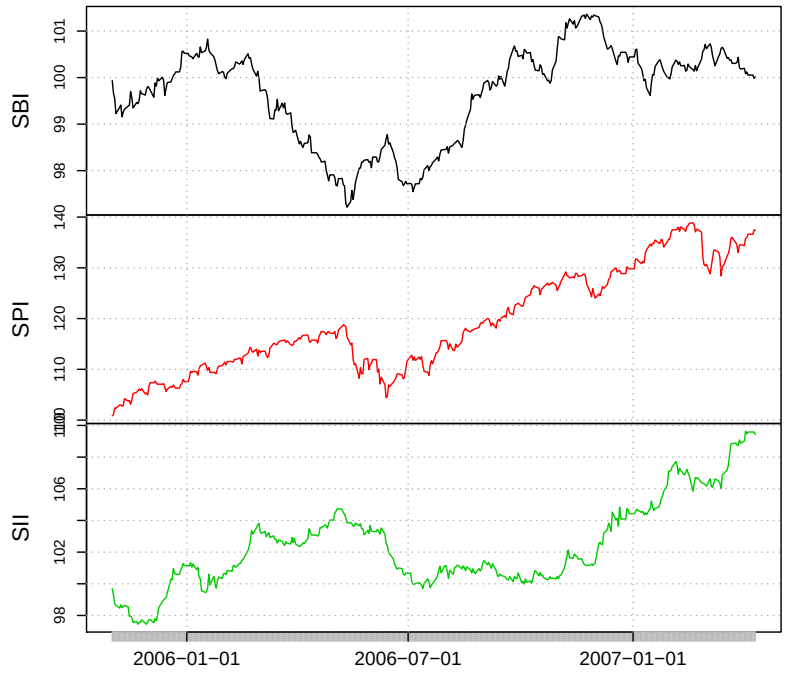


Figure 15: This graph shows a one column multiple plot layout. The one column layout is generated for up to four time series. When the multivariate time series has more then four time series then a two column layout is displayed. It is up to you which axis style you prefer, `at="pretty"` or `at="chic"`.

3.4 Time Axis - Two Column Multiple Plot Layout

Concerning the style of the axis, there is now difference between the one and two column plot designs.

```
> par(mfrow=c(1, 1))
> plot(tS6, plot.type="m", at="chic")
```

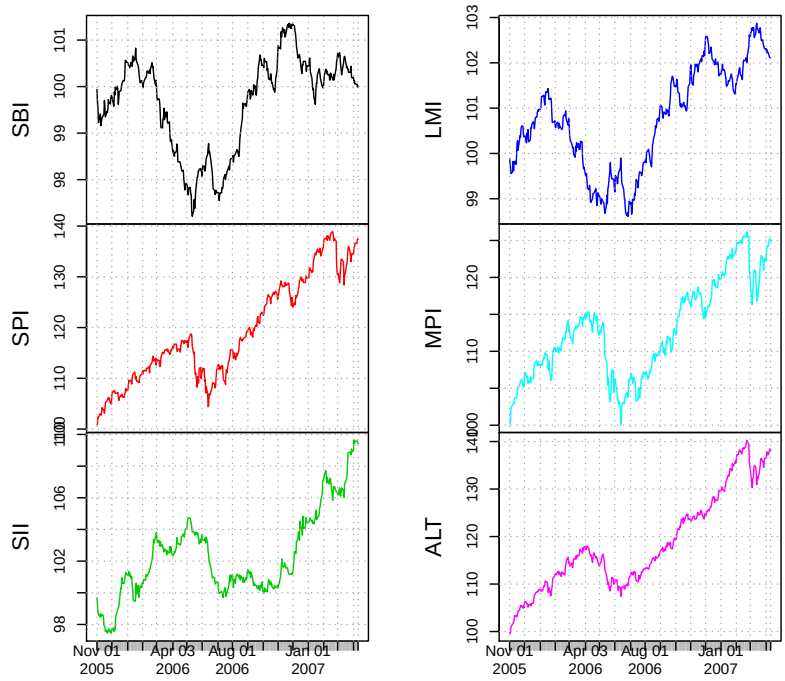


Figure 16: When we have more then four time series, then the display will be generated in two columns. Note, it is possible to modify the width of the gap between the two columns.

3.5 Tick and Format Layout: The <tailored> axis style

The third alternative to style the axis offers the users to define format positions according to his preferences. Here comes an example:

```
> par(mfrow=c(2, 1))
> at <- paste0("200", c("6-01", "6-04", "6-07", "6-10", "7-01", "7-04"), "-01")
> plot(tS3, plot.type="s", format="%B\n%Y", at=at)
> plot(tS3, plot.type="s", format="%b/%y", at=at)
```

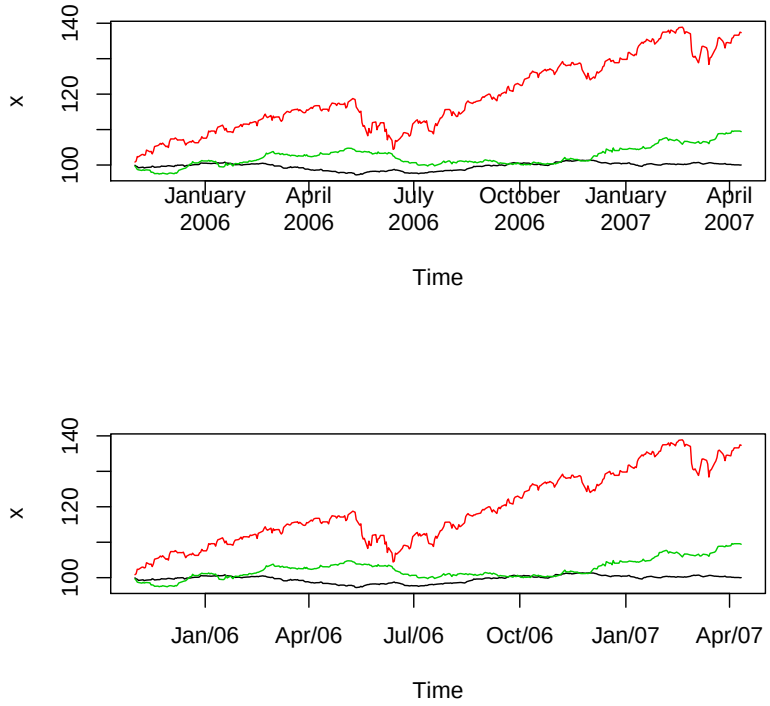


Figure 17: This graph shows plots with user tailored positions and formatted axis labels.

4 Annotations

Plot annotations are elelents which can be added to plots or completely discarded. To discard all annotations you have to set `ann=FALSE` in the argument list of the timSeries `plot` function. To display annotation you can call the function `title`. This allows to add the main title, the sub title, and the x- and y-labels to a plot. Together with the appropriate character strings, you can also specify the placement of these annotations by the arguments `line` and `outer`.

There are additional functions to add annotations to a plot. These are `text` and `mtext`.

4.1 Discarding all Annotations

In a default plot we display only the value-label(s) which are taken from the units or column names of the time time series object. Title, sub title, and time-label are not shown. To discard the appearance of all annotations on a plot you have to set the plot argument `ann=FALSE`.

```
> par(mfrow=c(2, 2))
> plot(tS1, ann=FALSE)
> plot(tS3, plot.type="s", ann=FALSE, at="pretty")
> plot(tS6, plot.type="s", ann=FALSE, at="pretty")
```

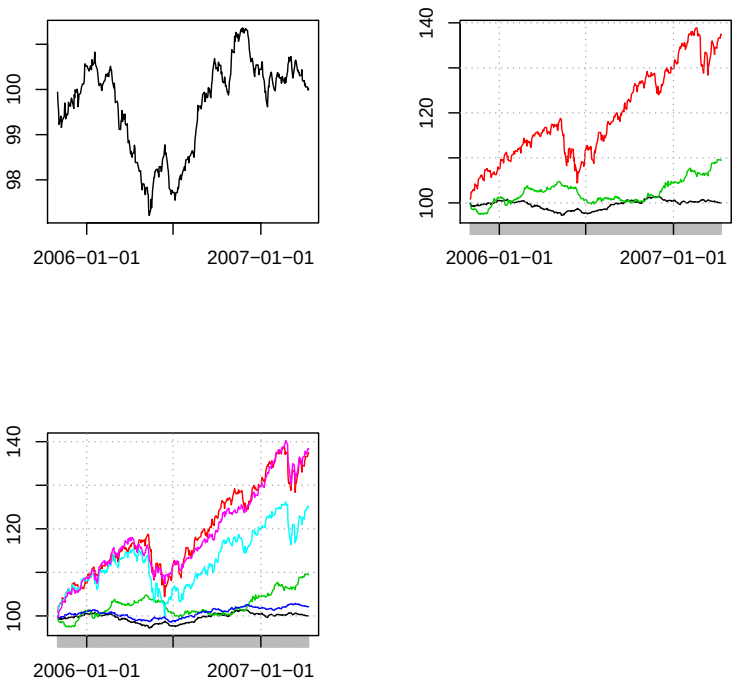


Figure 18: This graph shows a plot where all annotations have been discarded. Now feel free to add your own annotations.

4.2 Adding Title and Labels

To add a main title, a sub, title, and x- and y-labels you can call the function `title`.

```
> par(mfrow=c(2, 2))
> plot(tS1); title(main = "Index")
> plot(tS3, plot.type="s"); title(main = "Index")
> plot(tS3, plot.type="s"); title(main = "Index", xlab = "Date")
> plot(tS6, plot.type="s"); title(main = "Index", xlab = "Date")
```

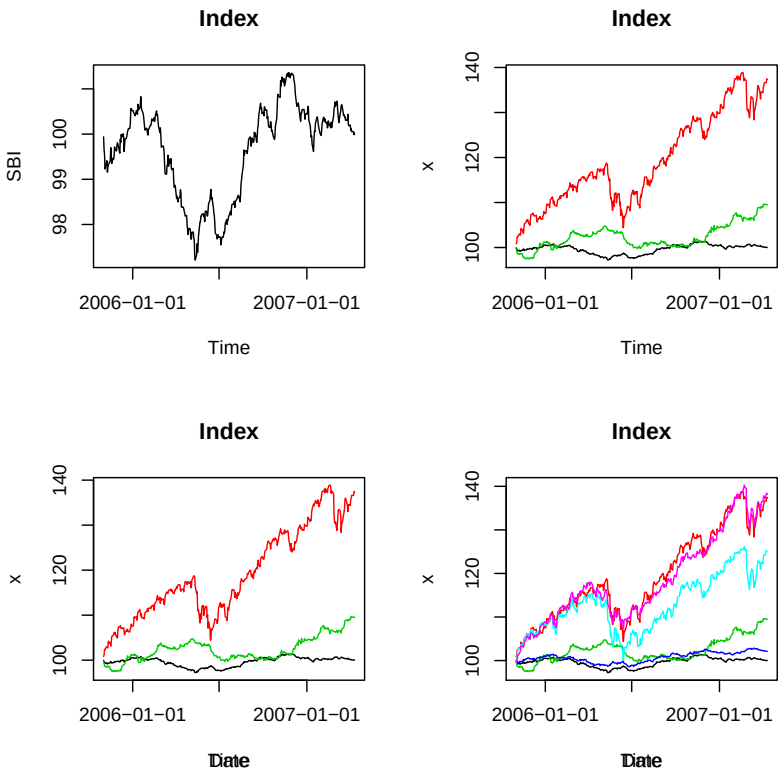


Figure 19: This graph displays in a two by two array four single plots. We have added title and x-lable annotations.

4.3 Changing Axis Font Size

Sometimes the axis font size may be considered as too small or too large. Then you can use the plot argument `cex.axis` to upsize or downsize the font.

```
> par(mfrow=c(3, 1))
> plot(tS3, at="chic", plot.type="s", cex.axis=0.75)
> plot(tS3, at="chic", plot.type="s", cex.axis=1.00)
> plot(tS3, at="chic", plot.type="s", cex.axis=1.25)
```

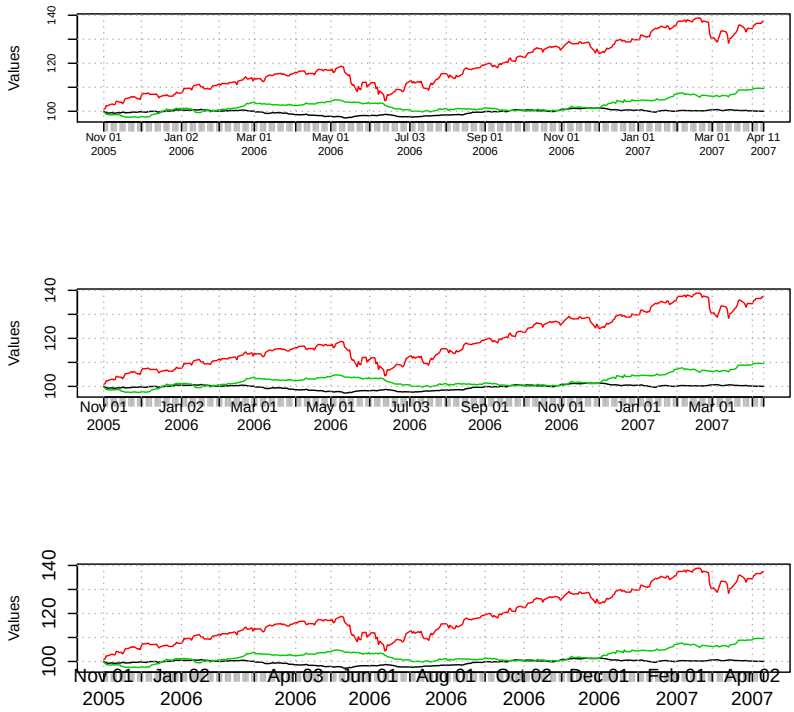


Figure 20: This is an example how to change the size of the axis labels relatively to its default value. The upper graph shows a font size decreased by 20%, the lower graph a font size increased by 25%. You can proceed in the same way when using the `"pretty"` axis style.

4.4 Flipping Value Axes

Flipping every second axis label in a multiple plot from left to rigth might be meaningful in the case when axis labels overwrite themselves.

```
> par(mfrow=c(1, 1))
> plot(tS3, plot.type="m", yax.flip = TRUE)
```

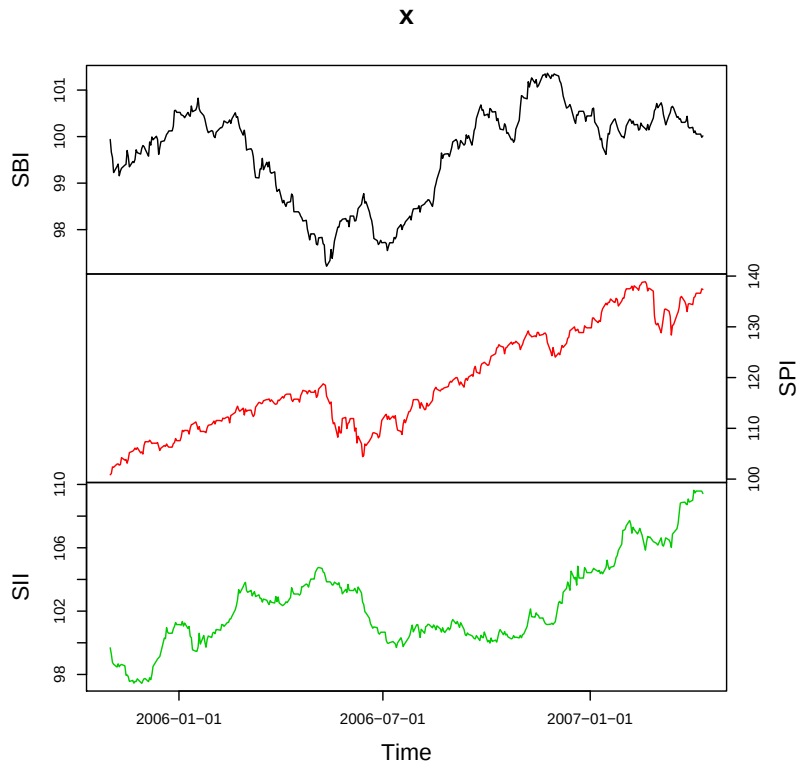


Figure 21: The graph shows an one column multiple plot, where the axis of the middle panel is flipped from the left to the right. Note, the same procedure can also be applied two two column multiple plots.

5 Decorations

There exist several options to decorate plots in different ways. Plot types (lines, points, horizontal bars, etc.) can be modified, colors can be changed, lines can be modified by style and seize, points can be selected by symbol and size.

In the following we will give some examples

- Modifying Types
- Changing Colors by Names
- Changing Colors by Color Palettes
- Changing Line Styles
- Modifying Line Widths
- Changing Plot Symbols
- Modifying Plot Symbol Sizes
- Discarding Grid Lines
- Drawing a Box

to show a few of the many types of cdecorations. Play around to achieve your perfect layout.

5.1 Modifying Types

```
> par(mfrow=c(1, 1))
> plot(tS3, plot.type="m", type=c("l", "p", "h"), at="pretty")
```

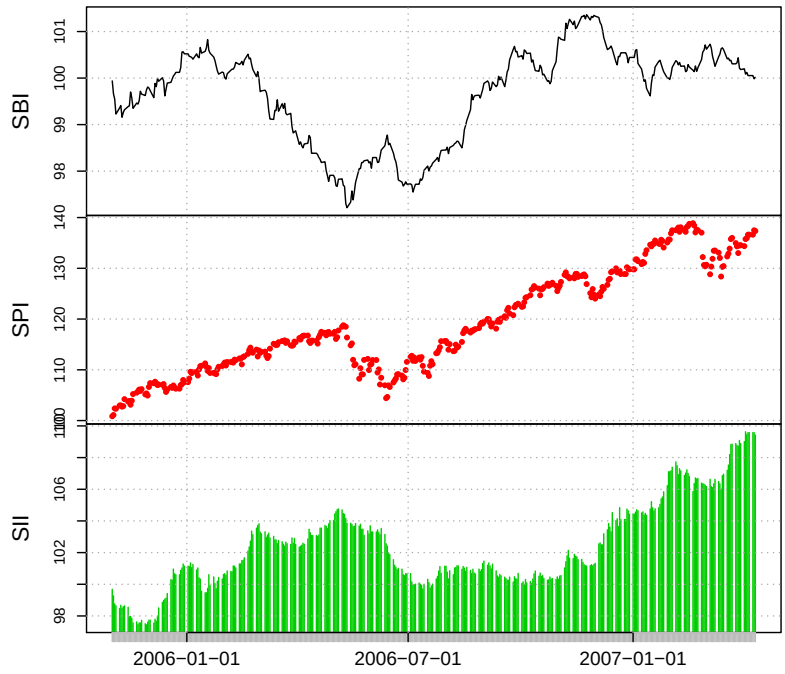


Figure 22: If we like to consider in a multiple plot for each panel its own plot style then we can set the parameter `type`.

5.2 Changing Colors by Names

Colors can be changed in several ways. Just by their numbers, e.g. 1 (black), 2 (red), 3 (green) etc., or by name, e.g. ”black”, ”red”, ”green”, etc. or by using well designed color palettes.

```
> par(mfrow=c(1, 1))
> plot(tS3, plot.type="m", col=c("blue", "orange", "darkgreen"))
```

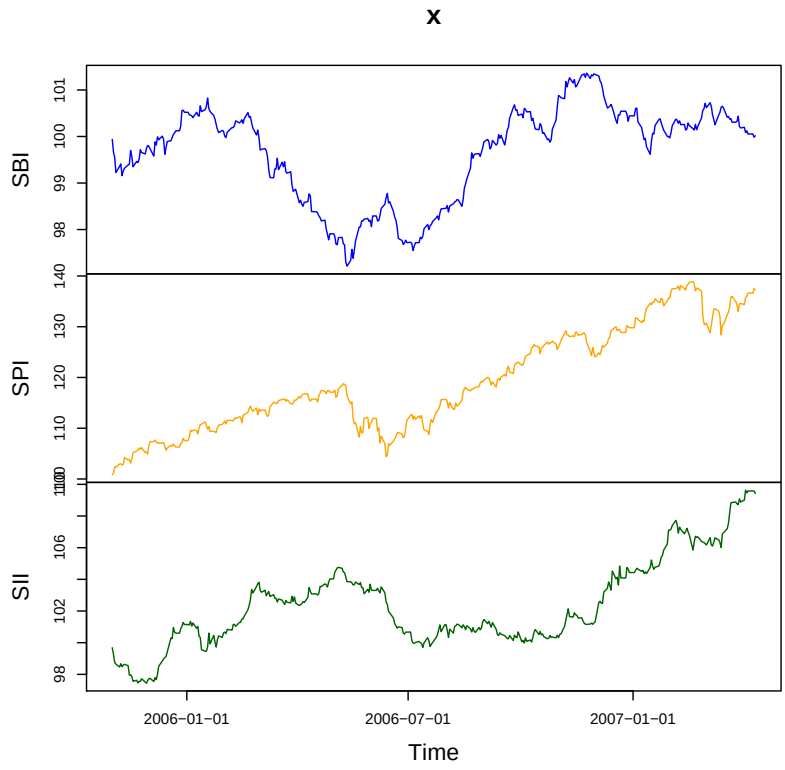


Figure 23: This graph shows how to assign colors by name in the case of a multiple plot. You can do it in the same way setting `plot.type="s"` if you like to display all three curves in a common single plot.

5.3 Changing Colors by Color Palettes

When the number of curves increases, then it can become quite difficult to find a set of nice colors. In such cases it is convenient to select the colors from color palettes.

```
> par(mfrow=c(1, 1))
> plot(tS6, plot.type="s", col=heat.colors(n=6, alpha = 1),
+   at="chic", format = "%B\n%Y")
```

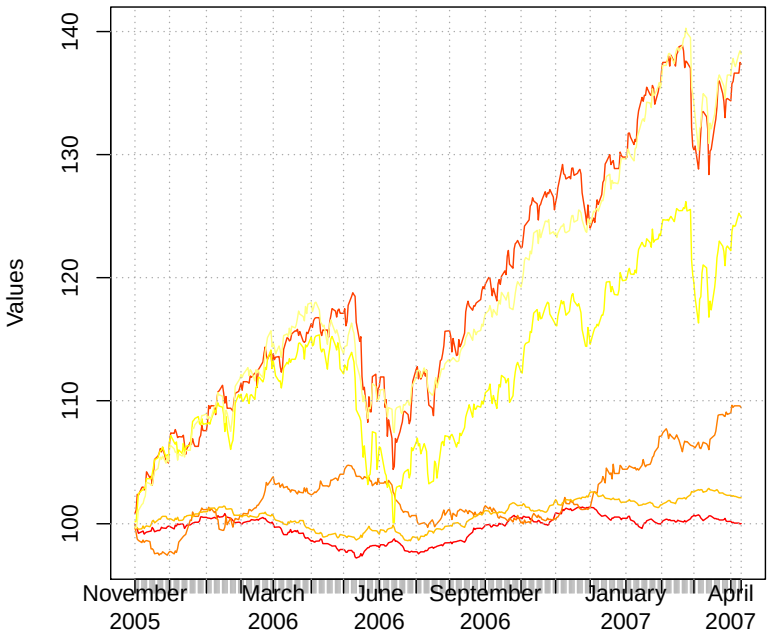


Figure 24: This graph shows an example of six curves diplayed in a sequence of reds. For this we called the function `seqPalette`.

```
FUNCTION:        COLOUR PALETTE

 rainbowPalette   Contiguous rainbow colour palette
 heatPalette      Contiguous heat colour palette
 terrainPalette   Contiguous terrain colour palette
 topoPalette      Contiguous topo colour palette
 cmPalette        Contiguous cm colour palette
 greyPalette      R's gamma-corrected gray palette
 timPalette       Tim's MATLAB-like colour palette
 rampPalette      Colour ramp palettes
 seqPalette       Sequential colour brewer palettes
 divPalette       Diverging colour brewer palettes
 qualiPalette     Qualified colour brewer palettes
 focusPalette     Red, green and blue focus palettes
 monoPalette      Red, green and blue mono palettes
```

5.4 Changing Line Styles

In multiple plot to each curve an own line style `lty` can be assigned: 0 ”blank”, 1 ”solid”, 2 ”dashed”, 3 ”dotted”, 4 ”dotdash”, 5 ”longdash”, or 6 ”twodash”.

```
> par(mfrow=c(1, 1))
> plot(tS3, plot.type="m", col=1, lty=1:3, at="chic")
```

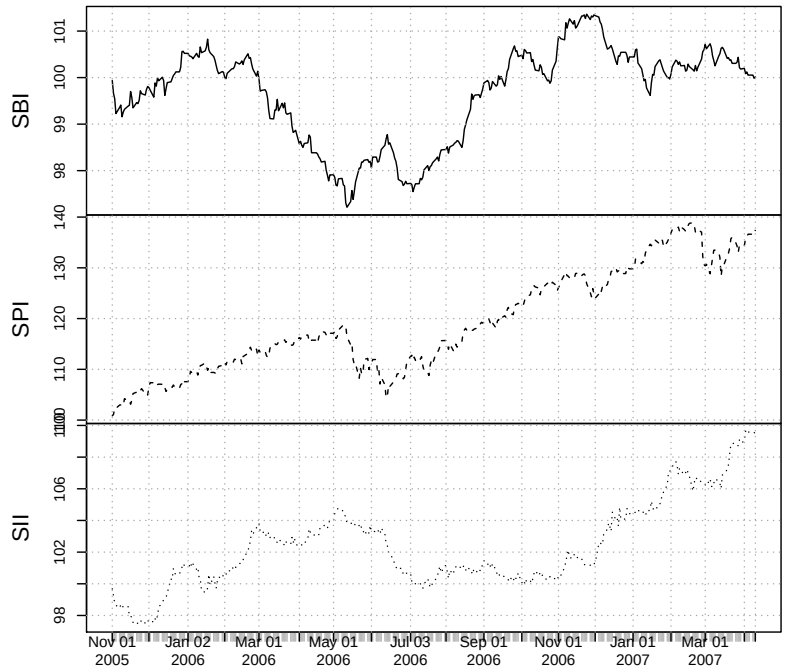


Figure 25: When we like to print plots in black and white, then its makes much sense to use different line types so that we can distinguish the curves one from each other.

5.5 Modifying Line Widths

Not only the line type, but also the line width can be modified for each curve in an individual kind.

```
> par(mfrow=c(1, 1))
> plot(tS3, plot.type="m", col=1, lwd=3:1, at="chic")
```

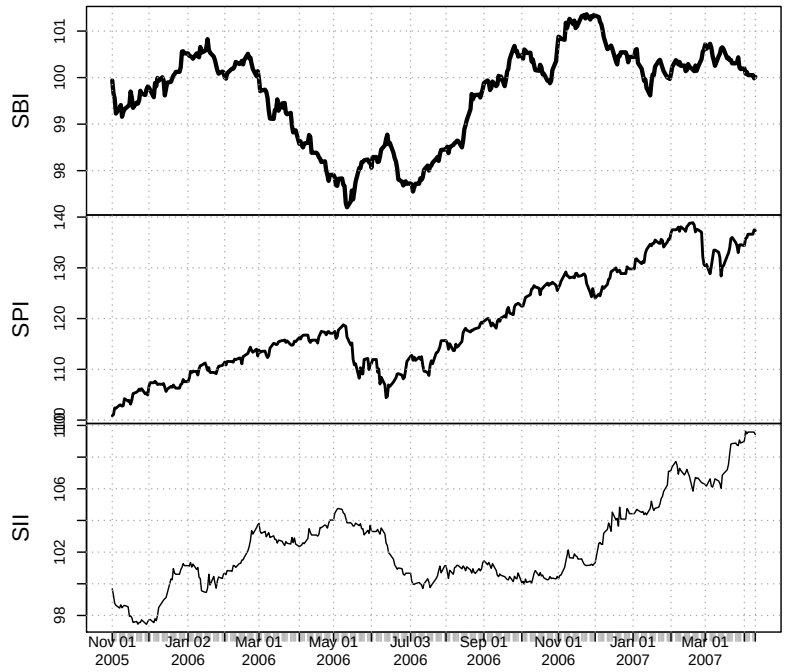


Figure 26: The graph shows three line widths, the upper's curve width is thick, the middle's curve width is medium, and the lowest's curve width is the thinnest one.

5.6 Changing Plot Symbols

To use different plot symbols we can assign them by the parameter `pch`. Don't forget also to set `type="p"`.

5.7 Modifying Plot Symbol Sizes

The argument `cex.pch` allows to increase or decrease plot symbol sizes with respect to the current plot symbol size.

```
> par(mfrow=c(1, 1))
> plot(tS3, plot.type="s", type="p",
+   col=1:3, pch=21:23, cex.pch=c(0.2, 0.2, 0.2), at="pretty")
```

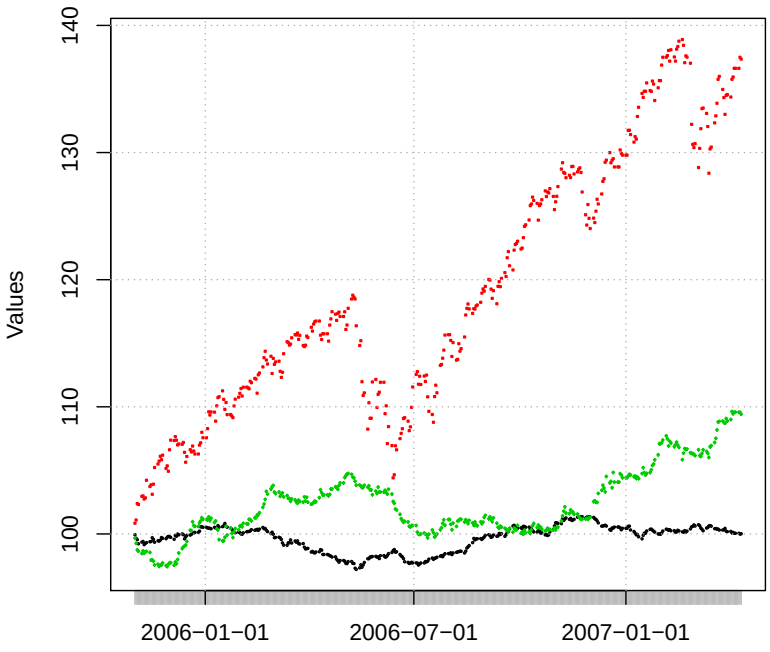


Figure 27: This plot show how to change the size of plot symbols in a single plot setting the argument `cex.pch`. Note, for each curve its own size can be set. The same approach can be used also for multiple plots.

5.8 Discarding Grid Lines

By default grid lines are displayed. To discard the grid lines from the plot set the arguments `grid=FALSE`.

```
> par(mfrow=c(1, 1))
> plot(tS3, plot.type="s", grid=FALSE)
```

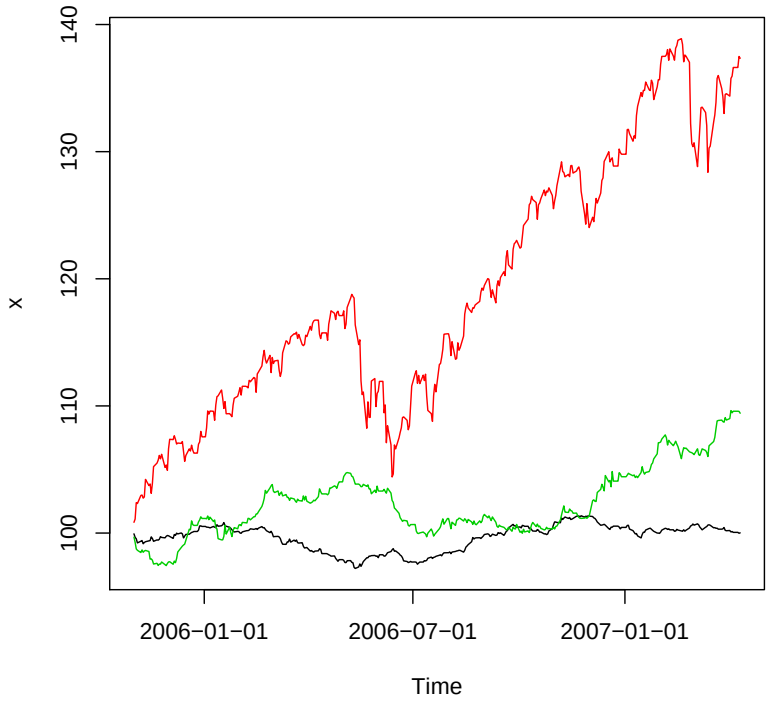


Figure 28: By default a grid is drawn on top of the plot. You can remove it by setting the argument `grid=FALSE`

5.9 Drawing a Box

```
> par(mfrow=c(1, 1))
> plot(tS3, plot.type="s", frame.plot=FALSE, grid=FALSE)
> box()
> box(bty = "7", col = "white") # boxL
> grid(NA, NULL, col = "darkgrey") # hgrid
```

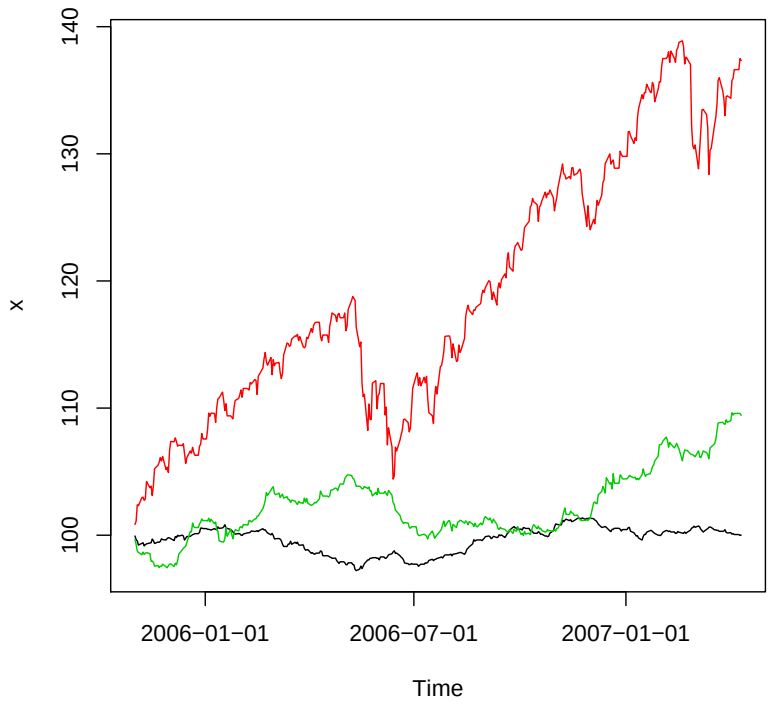


Figure 29: By default the plots are displayed as frame plots. This means that the graphs are surrounded by a box. This box can be discarded setting the plot argument `frame.plot=FALSE`.

6 The Panel Function

Multiple plots are very powerful plotting designs. Each panel in a graph can individually tailored by the user. By default each curve in a panel is generated by the function `lines`. You can define your own panel function(s) by setting the plot argument `panel` to a user dfined functions.

In the following we will show three examples.

6.1 Adding a Horizontal Zero Line

In this example we show how to write a panel function which allows to add a horizontal zero line to each plot panel.

```
> par(mfrow=c(1, 1))
> lines2 <- function(X, Y, type, xlab, ylab, col, pch, lty, lwd, cex) {
+   lines(x=X, y=Y, col=col)
+   abline(h=0, col = "brown", lwd=2)}
> plot(returns(tS3), plot.type="m", col = .colorwheelPalette(3),
+   panel=lines2, at="pretty")
```

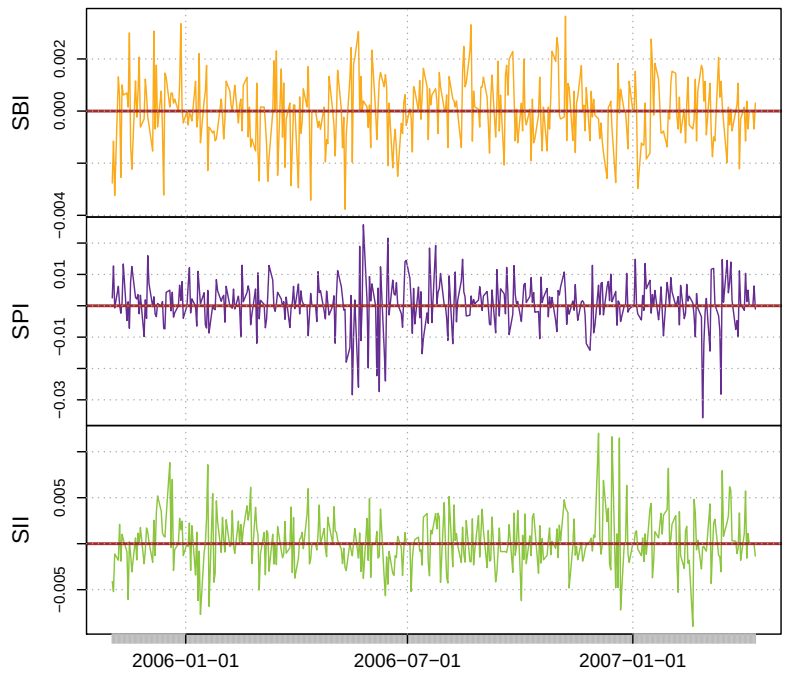


Figure 30: This multiple plot shows panels with curves having a horizontal zero reference line.

6.2 Adding an Rug to Multiple Return Plots

This example shows how to add in each panel rugs to the righ Y-axis.

```
> par(mfrow=c(1, 1))
> lines2 <- function(X, Y, type, xlab, ylab, col, pch, lty, lwd, cex) {
+   lines(x=X, y=Y, type="h", col=col)
+   rug(Y, side=4, col="steelblue") }
> plot(returns(tS6), plot.type="m", col = .colorwheelPalette(6),
+   panel=lines2, at="pretty")
```

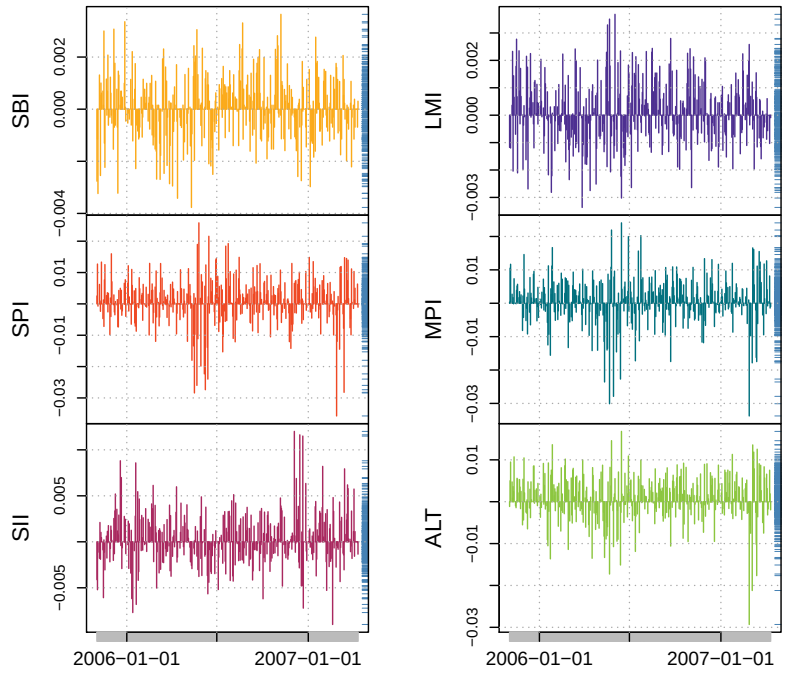


Figure 31: This multiple plot shows panels with rugs on the right Y-axis.

6.3 Adding an EMA to Multiple Index Plots

This example shows how to add an EMA indicator to each plot panel. The `emaTA()` function is provided by the `fTrading` package.

```
> par(mfrow=c(1, 1))
> lines2 <- function(X, Y, type, xlab, ylab, col, pch, lty, lwd, cex) {
+   lines(x=X, y=Y, type="l", col=col)
+   lines(x=X, y=emaTA(Y), col="black") }
> plot(tS3, plot.type="m", col = .colorwheelPalette(3), panel=lines2,
+   grid=TRUE, at="pretty")
```

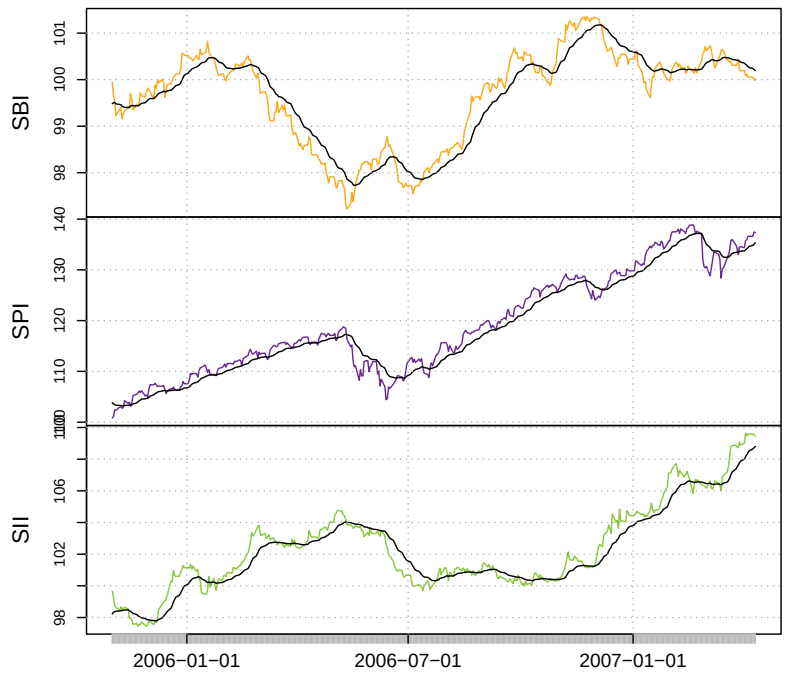


Figure 32: A multiple graph with EMA indicators in each panel.

7 Conclusions

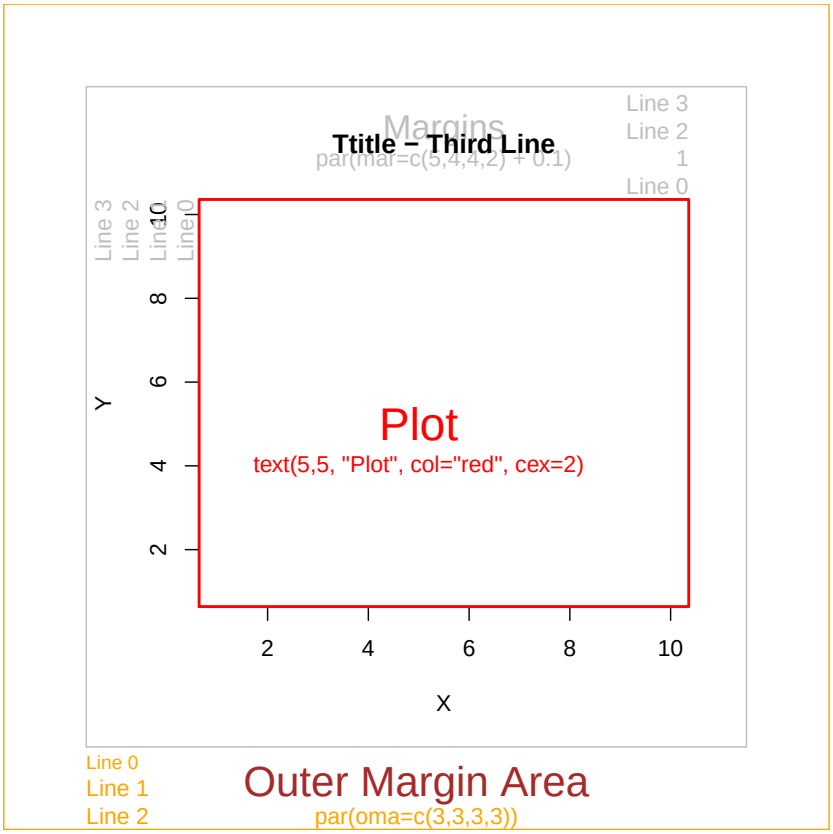
The `plot` function in the `timeSeries` package is a very powerful tool to create plots from time series objects. This includes to display univariate and multivariate time series in single and multiple panels, to select from two styles for the time-axis or even to tailor positions and formats according to his own needs, and to modifiy annotations and decorations of plots.

8 Appendix

In the appendix we have summarized graphs and tables which are useful tools to create plots. We have reprinted the default color table from R, we have summarized several color palettes as available in the `fBasics` package and other contributed R packages, and two tables with font characters and plot symbols.

8.1 Margins: mar and oma

```
> # Plot:
> # - oma stands for 'Outer Margin Area'
> # - mar represents the 'figure Margins'
> # - The default size is c(5,4,4,2) + 0.1
> # - The axes tick marks will go in the first lines
> par(mfrow=c(1, 1))
> par(oma=c(3,3,3,3))  # all sides have 3 lines of space
> par(mar=c(5,4,4,2) + 0.1)
> plot(x=1:10, y=1:10, type="n", xlab="X", ylab="Y")
> # Add Text tot the Plot Part - red
> text(5,5, "Plot", col="red", cex=2)
> text(5,4, "text(5,5, \"Plot\", col=\"red\", cex=2)", col="red", cex=1)
> box("plot", col="red", lwd=2)
> # Add text to thebThe Figure Part - grey
> mtext("Margins", side=3, line=2, cex=1.5, col="grey")
> mtext("par(mar=c(5,4,4,2) + 0.1)", side=3, line=1, cex=1, col="grey")
> mtext("Line 0", side=3, line=0, adj=1.0, cex=1, col="grey")
> mtext("     1", side=3, line=1, adj=1.0, cex=1, col="grey")
> mtext("Line 2", side=3, line=2, adj=1.0, cex=1, col="grey")
> mtext("Line 3", side=3, line=3, adj=1.0, cex=1, col="grey")
> mtext("Line 0", side=2, line=0, adj=1.0, cex=1, col="grey")
> mtext("Line 1", side=2, line=1, adj=1.0, cex=1, col="grey")
> mtext("Line 2", side=2, line=2, adj=1.0, cex=1, col="grey")
> mtext("Line 3", side=2, line=3, adj=1.0, cex=1, col="grey")
> box("figure", col="grey")
> # The title will fit in the third line on the top of the graph.
> title("Ttitle - Third Line")
> # Note 'outer=TRUE' moves us from the figure to the outer margins.
> mtext("Outer Margin Area", side=1, line=1, cex=1.8, col="brown", outer=TRUE)
> mtext("par(oma=c(3,3,3,3))", side=1, line=2, cex=1, col="orange", outer=TRUE)
> mtext("Line 0", side=1, line=0, adj=0.0, cex=0.8, col="orange", outer=TRUE)
> mtext("Line 1", side=1, line=1, adj=0.0, cex=1, col="orange", outer=TRUE)
> mtext("Line 2", side=1, line=2, adj=0.0, cex=1, col="orange", outer=TRUE)
> box("outer", col="orange")
```

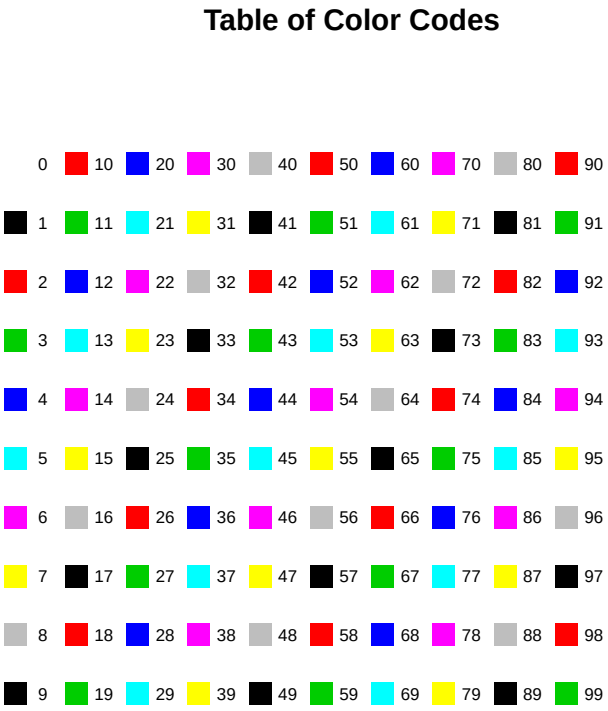

Margins
par(mar=c(5,4,4,2) + 0.1)
Line 3
Line 2
1
Line 0
Ttitle – Third Line
Line 3
Line 2
Line 1
Line 0
Y
2
4
6
8
10
Plot
text(5,5, "Plot", col="red", cex=2)
2
4
6
8
10
X
Line 0
Line 1
Line 2
Outer Margin Area
par(oma=c(3,3,3,3))

8.2 Character Table

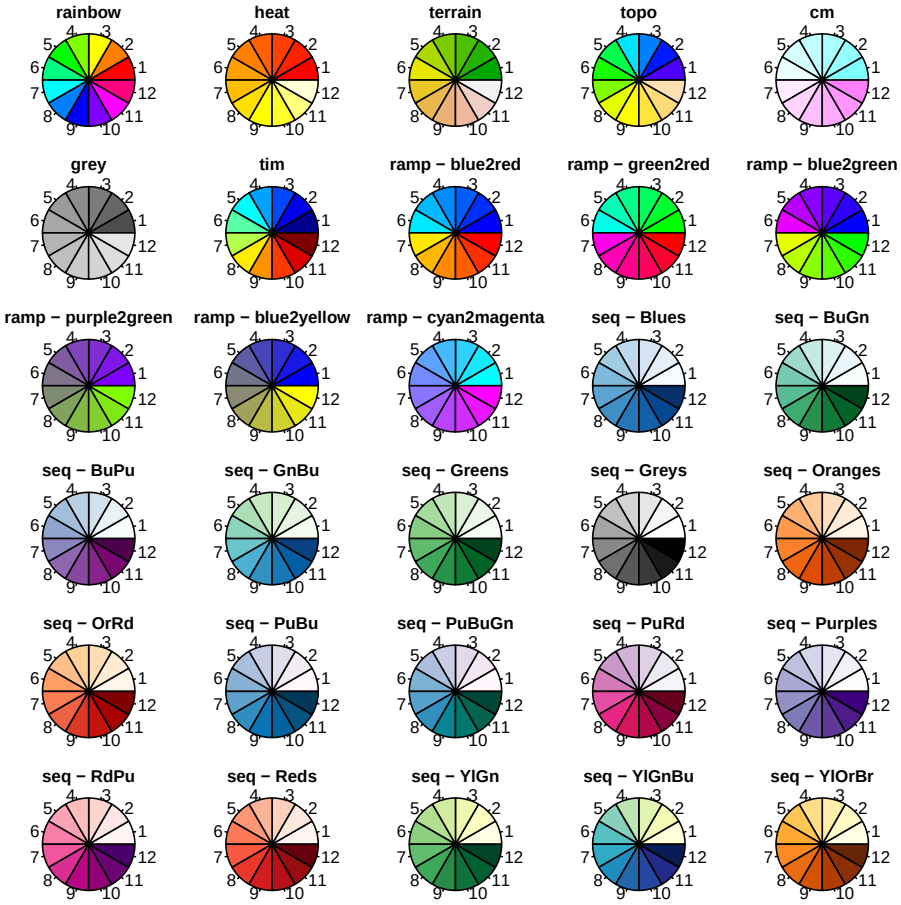
Table of Characters

	0	1	2	3	4	5	6	7
4		!	∀	#	∃	%	&	϶
5	(	)	*	+	,	−	.	/
6	0	1	2	3	4	5	6	7
7	8	9	:	;	<	=	>	?
10	≅	Α	Β	Χ	Δ	Ε	Φ	Γ
11	Η	Ι	ϑ	Κ	Λ	Μ	Ν	Ο
12	Π	Θ	Ρ	Σ	Τ	Υ	ς	Ω
13	Ξ	Ψ	Ζ	[	∴	]	⊥	_
14	‾	α	β	χ	δ	ε	φ	γ
15	η	ι	φ	κ	λ	μ	ν	ο
16	π	θ	ρ	σ	τ	υ	ϖ	ω
17	ξ	ψ	ζ	{	|	}	~	
20								
21								
22								
23								
24	€	ϒ	′	≤	⁄	∞	ƒ	♣
25	♦	♥	♠	↔	←	↑	→	↓
26	°	±	″	≥	×	∝	∂	•
27	÷	≠	≡	≈	…	—	⊕	↵
30	ℵ	ℑ	ℜ	℘	⊗	⊕	∅	∩
31	∪	⊃	⊇	⊄	⊂	⊆	∈	∉
32	∠	∇	®	©	™	∏	√	·
33	¬	∧	∨	⇔	⇐	⇑	⇒	⇓
34	◊	〈	®	©	™	Σ	⎛	⎜
35	⎝	⎡	⎪	⎣	⎧	⎨	⎝	⎜
36		〉	⌡	⎦	⎩	⎭	⎠	⎟
37	⎭	⎤	⎮	⎦	⎫	⎬	⎭	

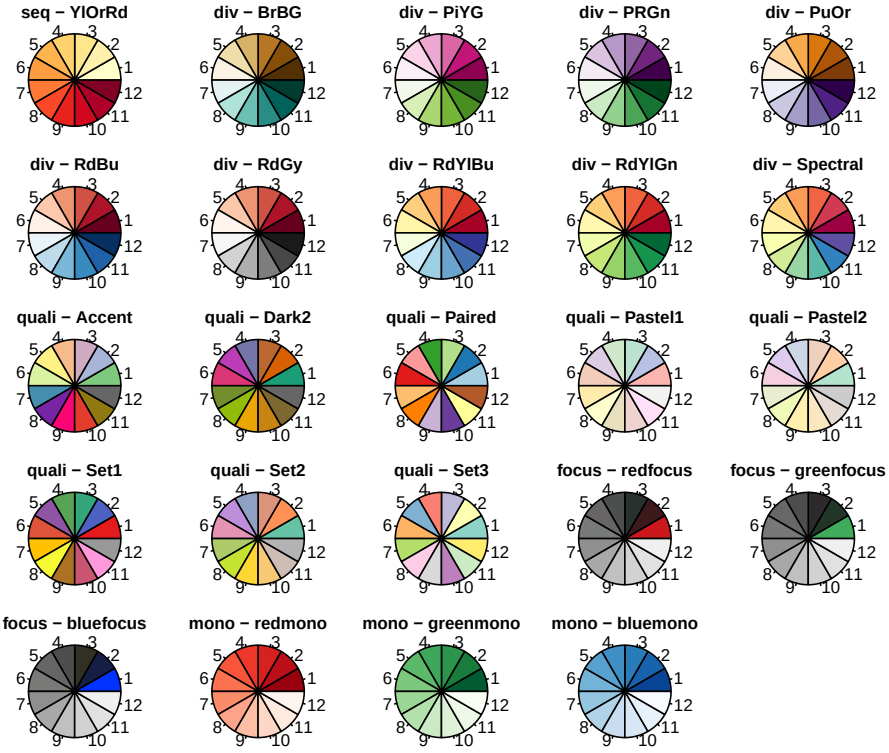
8.3 Color Table



8.4 Color Palettes I



8.5 Color Palettes II



8.6 Symbol Table

Table of Plot Characters

□	0	▽	25	2	50	K	75	d	100	}	125		150		175		200		225		250
○	1		26	3	51	L	76	e	101	~	126		151		176		201		226		251
△	2		27	4	52	M	77	f	102	•	127		152		177		202		227		252
+	3		28	5	53	N	78	g	103		128		153		178		203		228		253
×	4		29	6	54	O	79	h	104		129		154		179		204		229		254
◇	5		30	7	55	P	80	i	105		130		155		180		205		230		255
▽	6		31	8	56	Q	81	j	106		131		156		181		206		231		
⊠	7		32	9	57	R	82	k	107		132		157		182		207		232		
✳	8	!	33	:	58	S	83	l	108		133		158		183		208		233		
✣	9	"	34	;	59	T	84	m	109		134		159		184		209		234		
⊕	10	#	35	<	60	U	85	n	110		135		160		185		210		235		
✡	11	$	36	=	61	V	86	o	111		136		161		186		211		236		
⊞	12	%	37	>	62	W	87	p	112		137		162		187		212		237		
⊠	13	&	38	?	63	X	88	q	113		138		163		188		213		238		
⧄	14	'	39	@	64	Y	89	r	114		139		164		189		214		239		
■	15	(	40	A	65	Z	90	s	115		140		165		190		215		240		
●	16	)	41	B	66	[	91	t	116		141		166		191		216		241		
▲	17	*	42	C	67	\	92	u	117		142		167		192		217		242		
◆	18	+	43	D	68	]	93	v	118		143		168		193		218		243		
●	19	,	44	E	69	^	94	w	119		144		169		194		219		244		
•	20	-	45	F	70	_	95	x	120		145		170		195		220		245		
○	21	.	46	G	71	`	96	y	121		146		171		196		221		246		
□	22	/	47	H	72	a	97	z	122		147		172		197		222		247		
◇	23	0	48	I	73	b	98	{	123		148		173		198		223		248		
△	24	1	49	J	74	c	99	|	124		149		174		199		224		249		

8.7 Axis Style ”pretty”

```
> FORMAT <- tS1@format
> FORMAT
```

```
[1] "%Y-%m-%d"
```

```
> POSITIONS <- pretty(tS1)
> POSITIONS
```

```
GMT
[1] [2005-07-01] [2006-01-01] [2006-07-01] [2007-01-01] [2007-07-01]
```

```
> LABELS <- pretty(tS1)
> LABELS
```

```
GMT
[1] [2005-07-01] [2006-01-01] [2006-07-01] [2007-01-01] [2007-07-01]
```

8.8 Axis Style "chic"

```
> axTicksByTime <-
+ function (x, ticks.on = "auto", k = 1, labels = TRUE, format.labels = TRUE,
+     ends = TRUE, gt = 2, lt = 30)
+ {
+     if (timeBased(x)) x <- xts(rep(1, length(x)), x)
+     tick.opts <- c("years", "months", "weeks", "days", "hours", "minutes", "seconds")
+     tick.k.opts <- c(10, 5, 2, 1, 6, 1, 1, 1, 4, 2, 1, 30, 15, 1, 1)
+     if (ticks.on %in% tick.opts) {
+         cl <- ticks.on[1]
+         ck <- k
+     } else {
+         tick.opts <- paste(rep(tick.opts, c(4, 2, 1, 1, 3, 3, 1)), tick.k.opts)
+         is <- structure(rep(0, length(tick.opts)), .Names = tick.opts)
+         for (i in 1:length(tick.opts))
+         {
+             y <- strsplit(tick.opts[i], " ")[[1]]
+             ep <- endpoints(x, y[1], as.numeric(y[2]))
+             is[i] <- length(ep) - 1
+             if (is[i] > lt) break
+         }
+         nms <- rev(names(is)[which(is > gt & is < lt)])[1]
+         cl <- strsplit(nms, " ")[[1]][1]
+         ck <- as.numeric(strsplit(nms, " ")[[1]][2])
+     }
+     if (is.null(cl)) ep <- NULL else ep <- endpoints(x, cl, ck)
+     if (ends) ep <- ep + c(rep(1, length(ep) - 1), 0)
+     if (labels)
+     {
+         if (is.logical(format.labels) || is.character(format.labels))
+         {
+             unix <- ifelse(.Platform$OS.type == "unix", TRUE, FALSE)
+             time.scale <- periodicity(x)$scale
+             fmt <- ifelse(unix, "%n%b%n%Y", "%b %Y")
+             if (time.scale == "weekly" | time.scale == "daily")
+                 fmt <- ifelse(unix, "%b %d%n%Y", "%b %d %Y")
+             if (time.scale == "minute" | time.scale == "hourly")
+                 fmt <- ifelse(unix, "%b %d%n%H:%M", "%b %d %H:%M")
+             if (time.scale == "seconds")
+                 fmt <- ifelse(unix, "%b %d%n%H:%M:%S", "%b %d %H:%M:%S")
+             if (is.character(format.labels))
+                 fmt <- format.labels
+             names(ep) <- format(index(x)[ep], fmt)
+         } else {
+            names(ep) <- as.character(index(x)[ep])
+         }
+       ep
```

```
+    }
+ }
```

```
> ticks <- axTicksByTime(as.xts(tS1))
> ticks
```

```
Nov 01\n2005 Dec 01\n2005 Jan 02\n2006 Feb 01\n2006 Mar 01\n2006 Apr 03\n2006
           1           23           45           67           87          110
May 01\n2006 Jun 01\n2006 Jul 03\n2006 Aug 01\n2006 Sep 01\n2006 Oct 02\n2006
         130          153          175          196          219          240
Nov 01\n2006 Dec 01\n2006 Jan 01\n2007 Feb 01\n2007 Mar 01\n2007 Apr 02\n2007
         262          284          305          328          348          370
Apr 11\n2007
         377
```

About the Authors

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About Rmetrics

Rmetrics Open Source Project

With hundreds of functions built on modern methods, the Rmetrics open source software combines exploratory data analysis, statistical modelling and rapid model prototyping. The R/Rmetrics packages are embedded in R, building an environment which creates a first class system for applications in teaching statistics and finance. Rmetrics covers Time Series Econometrics, Hypothesis Testing, GARCH Modelling and Volatility Forecasting, Extreme Value Theory and Copulae, Pricing of Derivatives, Portfolio Analysis, Design and Optimization, and much more.

The Rmetrics Association
is a non-profit taking association working in the public interest. The Rmetrics Association provides support for innovations in financial computing. We believe that the Rmetrics Open Source software has become a valuable educational tool and that it is worth ensuring its continued development and the development of future innovations in software for statistical and computational research in finance. Rmetrics provides a reference point for individuals and institutions that want to support or interact with the Rmetrics development community. Rmetrics encourages students to participate in Rmetrics' activities in the context of Student Internships.

Rmetrics Software Evalution
If you like to get an impression of the size and quality of the Open Source Rmetrics Program have a look on the Ohloh Rmetrics Software Evaluation. The Evalutions gives an overview about the Software Development (Code Analysis, Estimated Cost), the people behind it, and its community.

Contributions to Rmetrics
are coming from several educuational institutions world wide. These include the Rmetrics web site and documentation project supported by ITP/CSE ETH Zurich, the organization of Summerschools and Workshops supported by ITP/CSE ETH Zurich, the R-sig-Finance Help and Mailing List, supported by SfS ETH Zurich, the R-forge development server, supported by University of Economics in Vienna, CRAN Test and Distribution Server for R software, supported by University of Economics Vienna, the Debian Linux integration supported by the Debian Association. Many thanks to all behind these projects who gave us continuous support over the last years.

Rmetrics Association
www.rmetrics.org

References

[1] Achim Zeileis and Gabor Grothendieck (2005): *zoo: S3 Infrastructure for Regular and Irregular Time Series.* Journal of Statistical Software, 14(6), 1-27. URL http://www.jstatsoft.org/v14/i06/

[2] Adrian Trapletti and Kurt Hornik (2007): *tseries: Time Series Analysis and Computational Finance.* R package version 0.10-11.

[3] Diethelm Würtz et al. (2007): *Rmetrics: Rmetrics - Financial Engineering and Computational Finance.* R package version 260.72. http://www.rmetrics.org

[4] International Organization for Standardization (2004): *ISO 8601: Data elements and interchage formats — Information interchange — Representation of dates and time* URL http://www.iso.org

[5] R Development Core Team: *R: A Language and Environment for Statistical Computing*, R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org

[6] Jeffrey A. Ryan (2008): *quantmod: Quantitative Financial Modelling Framework.* R package version 0.3-5. URL http://www.quantmod.com URL http://r-forge.r-project.org/projects/quantmod