S.f.Statistik, ETHZ

Tutorial (Unix Version)

February 26, 2010

Introduction

This tutorial will give you some basic knowledge about working with *R*. It will also help you to familiarize with an environment to work with *R* as it is provided in the computing labs in the ETH main building.

About *R*

R is free software (copyright: GNU public license) and is available from `http://stat.ethz.ch/CRAN/`. At this URL you find a comprehensive **Documentation**, `Manual`, "An Introduction to R" (about 100 pages `pdf`) and a shorter introduction `Contributed`, "R for Beginners / R pour les débutants" (31 pages, English/French).

R-environments

A "professional" way of working with *R* is to edit *R*-script files in an editor and to transfer the written code to a running *R* process. This can be set up on any platform. Below, we will describe one possible setting under Linux which was chosen for this exercise class. However, this is not the only possibility. Depending on which platform you are working on, we recommend the following:

linux Emacs with the add-on package Emacs Speaks Statistics (`http://stat.ethz.ch/ESS/`)

mac The built-in editor is already quite powerful (`http://cran.r-project.org/bin/macosx/`)

windows TinnR (`http://www.sciviews.org/Tinn-R/`) and WinEdt (`http://www.winedt.com/` and `http://cran.r-project.org/web/packages/RWinEdt/index.html`) both support R syntax highlighting and direct submission of *R* code

platform independent Java GUI for *R* (`http://jgr.markushelbig.org/JGR.html`) or Eclipse (`http://www.eclipse.org/`) with StatEt (`http://www.walware.de/goto/statet/`)

This tutorial will focus on working under Linux with the editor Kate (`http://www.kate-editor.org/`). It will also introduce a web-application (LEMUREN) to submit the code which you want to hand in. This setting corresponds to the environment on which you will be working during your exam.

Getting started on a dual-boot machine

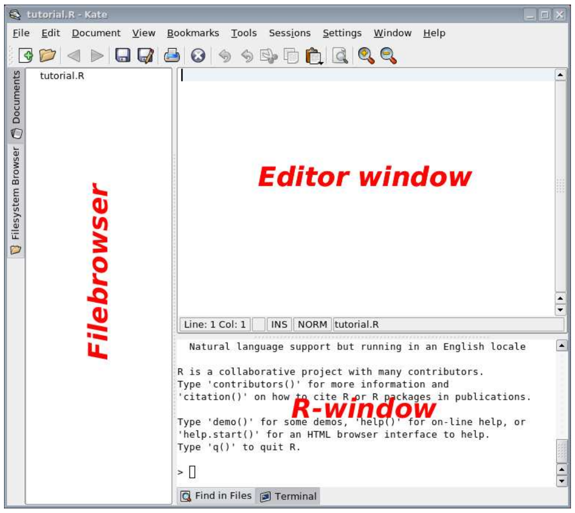
The computers in the computing labs of the ETH main building are dual-boot machines with Windows and Linux installed. If your computer is running under Windows, restart the machine and choose Linux when prompted to specify the operating system.

When the login screen is displayed, click on `Session` and choose KDE. Confirm your choice by clicking on `Change Session`. Enter your account information and log in (nethz name and password).

Getting started with Kate

We use *R* from within the Kate editor. To start Kate, click on the "Red Hat" in the Taskbar (at the bottom left of the screen), choose `Utilities` → `Editors` → `Advanced Text Editor (Kate)`[1]. Click on "New Session". Kate now shows 2 main windows: the left part is a file browser, the right part is the editor window.

Now we add a third window (see Figure 1) to start an *R* process: click on the *Console* button on the bottom of the editor window. This opens a terminal inside Kate. Type `R` on the command line followed by <*RETURN*>. An *R* process is started in the terminal. We will refer to this terminal as *R*-window from now on.



```
  Natural language support but running in an English locale

R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

> 
```

Figure 1: The working environment is set up: we are ready to start with the coding. Script files are edited in the editor window. *R*-code can be executed in the *R*-window.

To leave Kate, first quit the running *R* process by typing `q()` followed by <*RETURN*> in the *R*-window. Answer `n` to the question `Save workspace image? [y/n/c]`. Close Kate by selecting *File* → *Quit* in the menu.

To log out, click on the "Red Hat" in the Taskbar and choose `Log Out...`→ `End Current Session`.

R-basics

Type in the *R*-window:
`> x <- 2` <*RETURN*>
`> x` <*RETURN*>
Result: `[1] 2`

The assignment operator `<-` has created an object `x`. *R* is vector-oriented, so `x` is a vector with one element of value 2.

Next try (all commands have to be confirmed by <*RETURN*>; this is omitted from now on):
`> y <- c(3,5)` (c for combine)
`> y`
Result: `[1] 3 5`, a vector with two elements.

[1] Alternative: Open a terminal by clicking on the corresponding icon in the Taskbar. Type `kate` followed by <*RETURN*>

`ls()` shows all objects you have already generated. To remove `x`, use `rm(x)`.

Note that many functions are already defined in *R* (for example **c**, **t**, **max**, ...). We advise you to use different names for your variables to avoid confusion.

R includes demonstrations for many functions. You can get a list of all demonstrations with `demo()`. For example, take a look at the graphics demo of *R*: `demo(graphics)`. This will display a variety of plots generated by *R*. Hitting <*RETURN*>in the *R*-window will allow you to go from one graphic to the next one.

Working with an .R (script-)file

Click in the editor window. Save the file as *tutorial.R* via `File` → `Save As...`. From Now on, your *R* instructions should by typed in this script-file. Make sure to comment your code (with the symbol #) as you go on.

In the editor window *tutorial.R*, type `z <- c(8,13,21)` as first line and `2*z` as second line. Add an empty line at the end of your script.

You have several options to send your *R*-code to the *R*-window:

1. Click on `Tools` → `Pipe to Console`. All the code of your script is sent to the *R*-window.
2. Select only the first line (including the line break). Then click on `Tools` → `Pipe to Console`. Only the highlighted part of your script will be sent to the *R*-window.
3. Select the code to be sent to the *R*-window. Click with the middle mouse button on the line with the prompt in the *R*-window. The highlighted code is copied to the *R*-window.

If you forget to select the line break at the end of the selection (or don't have an empty line at the end of your script), the last instruction will not be executed in *R*. You will have to go in the *R*-window and confirm this last instruction by hitting <*RETURN*>.

It might be handy to define a shortcut for the command `Tools` → `Pipe to Console`. To set a new shortcut, go to `Settings` → `Configure Shortcuts...`. Click on `Pipe to Console` and set the radio-button to `Custom`. Enter a shortcut of your choice by hitting the corresponding key combination (e.g. <*`Shift`*> `+` <*RETURN*>). If you choose a key combination that is already in use for another command, you will get an error message. Once you chose your combination, quit the setup window by clicking on `OK`. From Now on you can send your *R*-script (or highlighted parts of it) to the *R*-window by pressing the defined key combination (e.g. <*`Shift`*> `+` <*RETURN*>).

From now on you should write (almost) all *R*-instructions into the *.R-file to evaluate them from there. At the end, you can save your script file by clicking on `File` → `Save`. If you open the file next time, click on `Tools` → `Pipe to Console` to restore your whole work. An alternative way to execute all instructions of the file *(path/)tutorial.R* is to execute `source("(path/)tutorial.R")` from *R*.

Computing with vectors

Type `fib <- c(1,1,2,3,5,z)` as next line of *tutorial.R* (gives the first eight Fibonacci-numbers). Evaluate the line, and take a look at `fib`. Type `2*fib+1`, `fib*fib` and `log(fib)` as next three lines of *tutorial.R*. Mark all three lines with the left mouse button and pipe them to the Console. This evaluates all marked lines. Check the results. Do you understand them?

Now create the sequence 2, 4, 6 as object s: `s <- 2*(1:3)`, alternatively `s <- seq(2,6,by=2)`. Take a look at `fib[3]`, `fib[4:7]`, `fib[s]`, `fib[c(3,5)]` and `fib[-c(3,5)]`.

Create a vector `x` with 8 elements, some of which are positive, some negative. Check `x > 0` and `fib[x > 0]`.

Don't forget to put comments in your script file. Up to now, it could for example look like this:

```
## Computational Statistics -- R tutorial
## Author: Hans Muster
## Date: 26 Feb 2010

## getting started
z <- c(8,13,21)
2*z

## computing with vectors
fib <- c(1,1,2,3,5,z)        # vector with first 8 Fibonacci numbers
fib
2*fib + 1                    # element-wise operations
fib*fib                      # element-wise multiplication
log(fib)                     # takes the log of each element
s <- 2*(1:3)                 # vector holding 2, 4, 6
s1 <- seq(2,6,by=2)          # same vector as s
fib[3]                       # 3rd element of vector fib
fib[4:7]                     # 4th, 5th, 6th and 7th element of fib
fib[s]                       # 2nd, 4th and 6th element of fib
fib[c(3,5)]                  # elements 3 and 5 of fib
fib[-c(3,5)]                 # vector fib without elements 3 and 5
x <- c(1,-3,5,-1,8,9,-2,1)   # new vector x
x > 0                        # elements 1, 3, 5, 6 and 8 of x are > 0
fib[x > 0]                   # elements 1, 3, 5, 6 and 8 of fib
```

Matrices: creation and computation

Create two vectors `x <- 1:4` and `y <- 5:8` and the matrices `mat1 <- cbind(x,y)` and `mat2 <- rbind(x,y,x+y)` (cbind means column-bind, rbind means row-bind). Take a look at the whole matrices `mat1` and `mat2` and try `mat2[3,2]`, `mat2[2,]` and `mat2[,1]`.

Computation with matrices using `+`, `*` etc. follows the same rules as computation with vectors, namely element-wise. For the matrix product, use `%*%`, e.g. `mat2 %*% mat1`.

Data Frames

A data frame is a generalized matrix. The main difference between data frames and matrices is that matrices need all elements to be of the same type (e.g. numeric, character), while data frames allow every column to have another type.

Reading and looking at datasets

ASCII-data is most easily read by the function `read.table`, which generates a data frame. `read.table` works also for datasets from the web. Try:

```
no2 <- read.table("http://stat.ethz.ch/Teaching/Datasets/no2Basel.dat",
                  header=TRUE)
```

You may examine the created object directly by typing `no2` in the *R*-window. Single variables are accessible by `no2[,"NO2"]`. You may take a look at the original file, in particular its first line, to understand why *R* knows the name of the variable. This can be done by calling the above URL from a web browser, e.g. Firefox. The parameter `header=TRUE` of `read.table` tells *R* that the variable names are in the first line. `no2` is still small enough, but in general it is useful to use the function `str` first, which displays the structure and type of an object, but not every single element: `str(no2)`. `summary(no2)` displays information about the columns of `no2`. `summary` extracts the most important information from lots of *R*-objects, e.g., the results of statistical tests or regression fits.

An alternative to `read.table` is the function `scan`, which reads vectors and lists. A list is a more general structure which may contain elements of different types and sizes, e.g. vectors of varying lengths, data frames, sublists, etc.

Graphics

Draw a histogram of the NO2-values of the no2-data.

```
par(mfrow = c(1,2))    # Number of pictures one below the
                       # other [1] or side by side [2]
                       # Important to save paper!
hist(no2[,"NO2"])      # draw histogram.
```

Now compute the regression line of the NO2-content against temperature and show it graphically next to the histogram:

```
lm.T <- lm(NO2 ~ Temp, data = no2)   # fits regression.
plot(NO2 ~ Temp, data = no2)
abline(lm.T, col = 4, lty = 2)       # col: colour; lty=2: dashed line
summary(lm.T)                        # regression summary (details later)
```

`title("Title xy")` adds a title to your graphic and `dev.print()` prints the graphic.

Note that there is a distinction between "high-level"- (such as `plot`, `hist`) and "low-level"-graphics functions (such as `abline`). The former make up a new graphic, while the latter add something to existing graphics.

Getting help

If you want to know the details about functions, you can use the *R*-online help. For example, `help(plot)` explains the `plot`-function. You can execute the example at the end of the help page by `example(plot)`.

An alternative to the `help`-function: `help.start()` starts the html-help of *R* in a web browser.

If you look for help about some topic without knowing the function names, e.g., about histograms, `help.search("histogram")` delivers a list of functions which correspond to the keyword. In parentheses you find the name of the package to which the function belongs. Most functions used by us in the beginning are contained in the package "base", which is automatically loaded. Other packages must be loaded by `library(package)`, before their functions and help pages are accessible.

Ending *R*

You can save your work by saving the file of instructions *tutorial.R* (see above; of course it is useful to use new files for new projects, e.g., *exercise1.R*, *exercise2.R*, ...). The instructions have to be evaluated again to restore your work. *R*-objects may be saved also by the functions `save` and `write` or by creating a new output file and use of the copy, cut and paste facilities of the editor.

The function `q()` terminates the *R*-session. Answer `n` to the question
`Save workspace image?  [y/n/c]` or use `q("no")`.

More to come

R can be used to create complex programs and functions. You may take a look at `help(for)` for control-flow constructs or at `help(function)` for creating functions.

Handing in your homework

If you want us to correct your solutions to the exercises, you should:

1. Print out important *R*-output and plots. Don't forget to add your interpretation of the *R*-output and plots and to answer the questions on the exercise sheet. A very elegant way to hand in your solution is to combine everything in a single file (for example by generating a `pdf` with LaTeX or OpenOffice).

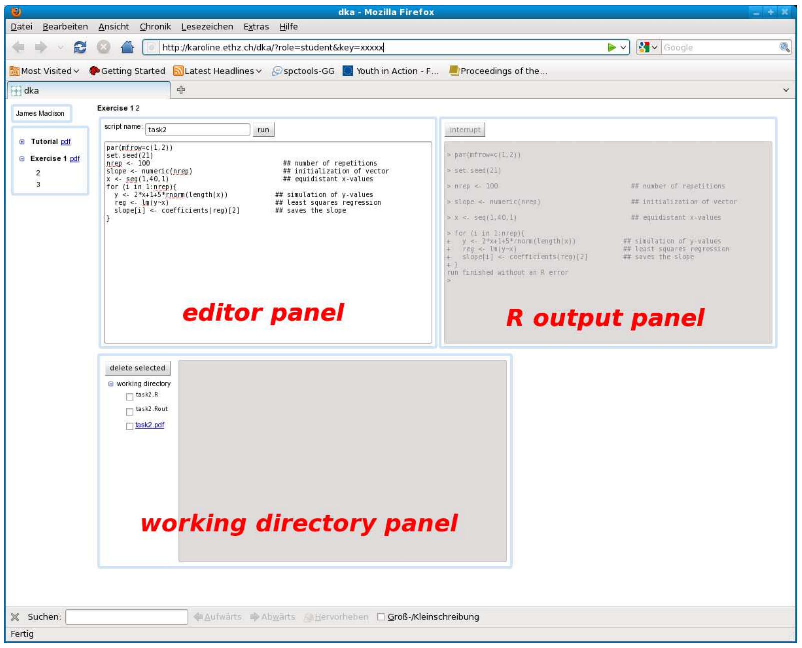
2. Submit your code on the LEMUREN web-interface. We will only correct code that has been submitted through this interface (don't print it out, don't send it to us by email). Also, we will only correct well documented code.

You have to open a web browser to access the LEMUREN interface: click on the Firefox icon in the Taskbar. Use the `URL` that was sent to you by email (something like `http://karoline.ethz.ch/dka/?role=student&key=xxxxx`).

In the upper left corner of the browser window you will see your name. In the menu below you can access the exercise sheets. You can download/open an exercise sheet by clicking on the corresponding `pdf` link. If you move the cursor of the mouse on to the name of an exercise sheet (for example "Exercise 1") you will see the deadline to hand in your solution. By clicking on the + sign in front of an exercise you can access the different tasks.

Click on the + in front of "Tutorial". Then click on "task". You see three panels (see Figure 2). The upper left one corresponds to the editor panel. The upper right one will display the *R*-output. The third one will display the content of the ".R" and ".Rout" files in your working directory.

Switch back to the editor `Kate`. Copy all the instructions contained in your file *tutorial.R* and paste them into the editor panel in LEMUREN. Click in the field `script name:` and



```
par(mfrow=c(1,2))
set.seed(21)
nrep <- 100                                 ## number of repetitions
slope <- numeric(nrep)                      ## initialization of vector
x <- seq(1,40,1)                            ## equidistant x-values
for (i in 1:nrep){
  y <- 2*x+1+5*rnorm(length(x))            ## simulation of y-values
  reg <- lm(y~x)                           ## least squares regression
  slope[i] <- coefficients(reg)[2]         ## saves the slope
}
```

```
> par(mfrow=c(1,2))

> set.seed(21)

> nrep <- 100                               ## number of repetitions

> slope <- numeric(nrep)                    ## initialization of vector

> x <- seq(1,40,1)                          ## equidistant x-values

> for (i in 1:nrep){
+   y <- 2*x+1+5*rnorm(length(x))          ## simulation of y-values
+   reg <- lm(y~x)                         ## least squares regression
+   slope[i] <- coefficients(reg)[2]       ## saves the slope
+ }
run finished without an R error
>
```

Figure 2: The LEMUREN interface: a handy tool to submit your solutions to the exercises and to get feedback regarding your code from the teaching assistants.

provide a name for your script. Do **not** include the ".R" in the name. Click on the button `run`. If there is no error in your script, all *R* instructions are carried out, and you see the output from *R* in the *R*-output panel. At the end of the buffer the message `run finished without an R error` should be displayed.

In addition, several files have been created and are now available in the working directory panel. Your script has been saved under the name you chose with the extension ".R". The output of *R* has been saved under the same filename with the extension ".Rout". If your code generated any plots, a file holding all the plots has been generated with the same filename with the extension ".pdf".

You can click on the file names in the working directory. If you click on a ".pdf" file, you can open/download it. If you click on a ".R" or ".Rout" file, the content of the file is displayed in the buffer. You can delete files that you do not need anymore by checking the corresponding boxes and then clicking on `delete selected`.

The teaching assistants will be able to see all the files that you have in your working directories.

A few things to keep in mind:

- When you click on the "run" button, the whole script is evaluated in *R* (not submitted line by line). Before being evaluated, your script is parsed (with the function `parse`). A syntax error (including an incomplete expression) will return an error.
- Instead of clicking on the "run" button, you can also type <*`Shift`*> `+` <*`RETURN`*> in the editor panel to evaluate your script.
- While your script is being evaluated, a wheel is turning next to the "run" button.

- If you want to stop the evaluation of a script, click on the “interrupt” button.
- If you want to save your plots one by one, you can use the function `pdf` in your script.
- If you need help from the teaching assistants for a particular problem, you can prepare a script called `help_request.R`. Once you submitted your help request in LEMUREN, send an email to `compstat@stat.math.ethz.ch` with the indication where we can find your code (for example in “Exercise 1”, “Task 2”). Make sure to structure your requests for help as it is mentioned in the “organizational sheet” of the lecture.
- LEMUREN is a nice tool to submit your code and requests for help. However, we strongly advise you not to develop your code on LEMUREN. It is better to become familiar with an editor to which you will still have access after this lecture is over. Therefore, develop your scripts with the editor of your choice, then submit your code via the LEMUREN web interface.