

Computing in R: exercises

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The objective of these computer exercises is to become familiar with the basic structure of R and to learn some more sophisticated tips and tricks of R. The R code to perform the analyses, together with the output, is given in a separate file. However, you are strongly advised to write the code yourself. Questions are posed to reflect on what you are doing and to study output and results in more detail.

1 Basics

If you have not done so already, start R via **Starten - Alle programma's - R - R 4.4.3** (older versions of R should also be fine). This opens the R console. R is a command line driven environment. This means that you have to type in commands (line-by-line) for it to compute or calculate something. In its simplest form R can therefore be used as a pocket calculator:

```
2+2
```

```
# [1] 4
```

Question 1. (a) Look up today's exchange rate of the euro versus the US\$ on the Internet. Use R to calculate how many US\$ is 15 euro.

Answer

```
# This is more or less the current exchange rate
15 * 1.08329

# [1] 16.24935

# It is better to use a variable to store the exchange rate
exrate <- 1.08329
exrate

# [1] 1.08329
15 * exrate

# [1] 16.24935
```

(b) Round the number you found to the second decimal using function `round` (use `help` or `?` to inspect the arguments of the function) and assign the result to an object `curr`.

Answer

```
curr <- round(15 * exrate, digits = 2)
curr

# [1] 16.25
```

(c) Use `mode`, `str`, and `summary` to inspect the object you created. These functions give a compact display of the type of object and its contents.

Answer

```
mode(curr)

# [1] "numeric"
str(curr)

# num 16.2
summary(curr)

#   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
#  16.25  16.25   16.25   16.25  16.25   16.25
```

Luckily R is more than just a calculator, it is a programming language with most of the elements that every programming language has: statements, objects, types, classes *etc.*

2 R syntax: vectors

Question 2. (a) One of the simplest data structures in R is a vector. Use the function `seq` to generate a vector `vec` that consists of all numbers from 11 to 30 (see `?seq` for documentation).

Answer

```
vec <- seq(11,30)
vec

# [1] 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
```

(b) Select the 7th element of the vector.

Answer

```
vec[7]

# [1] 17
```

(c) Select all elements except the 15th.

Answer

```
# Use '-' to exclude elements
vec[-15]

# [1] 11 12 13 14 16 17 18 19 20 21 22 23 24 26 27 28 29 30
```

(d) Select the 2nd and 5th element of the vector.

Answer

```
# Use the concatenate function 'c'  
vec[c(2,5)]
```

```
# [1] 12 15
```

(e) Select only the odd valued elements of the vector `vec`. Do this in two steps: first create the appropriate vector of indices `index` using the function `seq`, then use `index` to make the selection.

Answer

```
# Instead of "hard coding" the length of the vector by specifying the value 20,  
# you can calculate it using the function 'length'. This makes your code more  
# generic and less error prone  
index <- seq(1,length(vec),by=2)  
vec[index]
```

```
# [1] 11 13 15 17 19 21 23 25 27 29
```

Until now you have only used the R console. However, RStudio (**Starten - Alle programma's - R - RStudio**) provides a much nicer and richer interface when working with R. Although all exercises can be made within the basic R environment, we highly recommend to use RStudio.

Question 3. (a) What are the windows that RStudio consists of?

Answer

The most important ones are Script, Console, Environment, History, Files, Plots, Packages, Help, Viewer.

From now on we advise you to use RStudio. You can use either the Console or the Script window (the upper left window). We recommend you to use the Script window, since this allows you to easily save your code to a file for later usage.

(b) Use the elementary functions `/`, `-`, `^` and the functions `sum` and `length` to calculate the mean $\bar{x} = \sum_i x_i/n$ and the standard deviation $\sqrt{\sum_i (x_i - \bar{x})^2 / (n - 1)}$ of the vector `vec` of all numbers from 11 to 30. You can verify your answer by using the built-in R functions `mean` and `sd`.

Answer

```
# Don't call the variable 'mean' since the function 'mean' already exists  
xmean <- sum(vec)/length(vec)  
xmean
```

```
# [1] 20.5
```

```
mean(vec)
```

```
# [1] 20.5
```

```
# Calculate the standard deviation in three (baby) steps  
numerator <- sum((vec-xmean)^2)  
denominator <- (length(vec)-1)  
xstd <- sqrt(numerator/denominator)  
xstd
```

```
# [1] 5.91608
```

```
sd(vec)
```

```
# [1] 5.91608
```

(c) Once you completed the analysis, have a look at the Environment and History windows. Do you

understand their contents?

Question 4. R comes with many predefined datasets. You can type `data()` to get the whole list. The `islands` dataset gives the areas of the world's major landmasses exceeding 10,000 square miles. It can be loaded by typing:

```
# This could in this case actually be skipped since the package datasets is
# already loaded
data(islands)
```

- (a) Inspect the object using the functions `head`, `str` etc. Also have a look at the help file using `help(islands)`.
- (b) How many landmasses in the world exceeding 10,000 square miles are there?

Answer

```
# From ?islands: "Description: The areas in thousands of square miles of
# the landmasses which exceed 10,000 square miles." So all of them:
length(islands)

# [1] 48
```

- (c) Make a Boolean vector that has the value TRUE for all landmasses exceeding 20,000 square miles.

Answer

```
# Remember that area was given in thousands of square miles
islands.more20 <- (islands > 20)
```

- (d) Select the islands with landmasses exceeding 20,000 square miles.

Answer

```
# Use the Boolean vector islands.more20 to select the ones with value TRUE
islands[islands.more20]
```

#	Africa	Antarctica	Asia	Australia	Baffin
#	11506	5500	16988	2968	184
#	Banks	Borneo	Britain	Celebes	Celon
#	23	280	84	73	25
#	Cuba	Devon	Ellesmere	Europe	Greenland
#	43	21	82	3745	840
#	Hispaniola	Hokkaido	Honshu	Iceland	Ireland
#	30	30	89	40	33
#	Java	Luzon	Madagascar	Mindanao	Moluccas
#	49	42	227	36	29
#	New Guinea	New Zealand (N)	New Zealand (S)	Newfoundland	North America
#	306	44	58	43	9390
#	Novaya Zemlya	Sakhalin	South America	Sumatra	Tasmania
#	32	29	6795	183	26
#	Victoria				
#	82				

- (e) Make a character vector that only contains the names of the islands.

Answer

```
islands.names <- names(islands)
```

(f) The Moluccas have mistakenly been counted as a single island. The largest island of the Moluccas, Halmahera, only has about 7,000 square miles. Remove Moluccas from the data. Hint: an elegant solution uses the Boolean operator `!=`.

Answer

```
notMoluccas <- islands.names != "Moluccas"
islands.withoutMoluccas <- islands[notMoluccas]
# Another solution is:
islands.withoutMoluccas <- subset(islands, islands.names!="Moluccas")
```

3 R syntax: matrices

Question 5. (a) Create a character matrix `M` with 6 rows and three columns containing the first eighteen letters of the Roman alphabet (hint: see `?letters`). Fill the matrix column-wise.

Answer

```
letters

# [1] "a" "b" "c" "d" "e" "f" "g" "h" "i" "j" "k" "l" "m" "n" "o" "p" "q" "r" "s"
# [20] "t" "u" "v" "w" "x" "y" "z"
M <- matrix(letters[1:18], nrow = 6, ncol = 3)
M

#      [,1] [,2] [,3]
# [1,] "a"  "g"  "m"
# [2,] "b"  "h"  "n"
# [3,] "c"  "i"  "o"
# [4,] "d"  "j"  "p"
# [5,] "e"  "k"  "q"
# [6,] "f"  "l"  "r"
```

(b) Which is the letter on the fifth row and second column?

Answer

```
M[5, 2]

# [1] "k"
```

(c) Replace the letters in the last column of `M` with the last six letters of the Roman alphabet.

Answer

```
M[,3] <- letters[21:26]
M

#      [,1] [,2] [,3]
# [1,] "a"  "g"  "t"
# [2,] "b"  "h"  "u"
# [3,] "c"  "i"  "v"
# [4,] "d"  "j"  "w"
# [5,] "e"  "k"  "x"
# [6,] "f"  "l"  "y"
```

```
# [1,] "a" "g" "u"
# [2,] "b" "h" "v"
# [3,] "c" "i" "w"
# [4,] "d" "j" "x"
# [5,] "e" "k" "y"
# [6,] "f" "l" "z"
```

(d) Make a character vector containing all the vowels and use this vector to replace the vowels in M with the character string “vowel”.

Answer

```
# Let's assume that "y" is also a vowel
vowels <- c("a","e","i","o","u","y")
M[M %in% vowels] <- "vowel"
M

#      [,1]  [,2]  [,3]
# [1,] "vowel" "g"   "vowel"
# [2,] "b"    "h"   "v"
# [3,] "c"    "vowel" "w"
# [4,] "d"    "j"   "x"
# [5,] "vowel" "k"   "vowel"
# [6,] "f"    "l"   "z"
```

(e) Now replace all consonants in M with the character string “consonant”.

Answer

```
# '!=': not equal to
M[M!="vowel"] <- "consonant"
M

#      [,1]      [,2]      [,3]
# [1,] "vowel"    "consonant" "vowel"
# [2,] "consonant" "consonant" "consonant"
# [3,] "consonant" "vowel"    "consonant"
# [4,] "consonant" "consonant" "consonant"
# [5,] "vowel"    "consonant" "vowel"
# [6,] "consonant" "consonant" "consonant"
```

(f) Count the number of elements in M that are equal to “consonant” and “vowel” respectively.

Answer

```
sum(M=="consonant")

# [1] 13
sum(M=="vowel")

# [1] 5
```

4 Data frames, data import, missing values and factors

Question 6. We are going to use yet another predefined dataset: `mtcars`. These data were extracted from the 1974 Motor Trend US magazine, and comprise fuel consumption and 10 aspects of automobile design and performance for 32 automobiles (1973–74 models). See `?mtcars` for the definition of the variables contained in it.

(a) What kind of data structure is the `mtcars` data?

Answer

```
# See '?mtcars', it is a data frame. On the command line you can use 'class' or 'str'
class(mtcars)

# [1] "data.frame"

str(mtcars)

# 'data.frame': 32 obs. of 11 variables:
# $ mpg : num  21 21 22.8 21.4 18.7 18.1 14.3 24.4 22.8 19.2 ...
# $ cyl : num  6 6 4 6 8 6 8 4 4 6 ...
# $ disp: num  160 160 108 258 360 ...
# $ hp  : num  110 110 93 110 175 105 245 62 95 123 ...
# $ drat: num  3.9 3.9 3.85 3.08 3.15 2.76 3.21 3.69 3.92 3.92 ...
# $ wt  : num  2.62 2.88 2.32 3.21 3.44 ...
# $ qsec: num  16.5 17 18.6 19.4 17 ...
# $ vs  : num  0 0 1 1 0 1 0 1 1 1 ...
# $ am  : num  1 1 1 0 0 0 0 0 0 0 ...
# $ gear: num  4 4 4 3 3 3 3 4 4 4 ...
# $ carb: num  4 4 1 1 2 1 4 2 2 4 ...
```

(b) How many car models can ride more than 25 miles per gallon?

Answer

```
sum(mtcars$mpg > 25)

# [1] 6
# Other solutions using different ways of extracting a column from a data frame
sum(mtcars[,"mpg"] > 25)

# [1] 6
sum(mtcars["mpg"] > 25)

# [1] 6
sum(mtcars[,1] > 25)

# [1] 6
```

(c) What are the names of the car models that can ride more than 25 miles per gallon?

Answer

```
rownames(mtcars[mtcars$mpg > 25,])
```



```
# [1] "Fiat 128"      "Honda Civic"    "Toyota Corolla" "Fiat X1-9"
# [5] "Porsche 914-2" "Lotus Europa"
```

(d) Select the car models that can ride less than 22 miles per gallon and have more than 6 cylinders.

Answer

```
# Use the Boolean operator '&' (logical AND)
mtcars[(mtcars$mpg < 22) & (mtcars$cyl > 6), ]

#           mpg cyl  disp  hp  drat   wt  qsec vs  am  gear  carb
# Hornet Sportabout  18.7   8  360.0 175  3.15  3.440 17.02  0  0    3    2
# Duster 360        14.3   8  360.0 245  3.21  3.570 15.84  0  0    3    4
# Merc 450SE        16.4   8  275.8 180  3.07  4.070 17.40  0  0    3    3
# Merc 450SL        17.3   8  275.8 180  3.07  3.730 17.60  0  0    3    3
# Merc 450SLC       15.2   8  275.8 180  3.07  3.780 18.00  0  0    3    3
# Cadillac Fleetwood 10.4   8  472.0 205  2.93  5.250 17.98  0  0    3    4
# Lincoln Continental 10.4   8  460.0 215  3.00  5.424 17.82  0  0    3    4
# Chrysler Imperial 14.7   8  440.0 230  3.23  5.345 17.42  0  0    3    4
# Dodge Challenger  15.5   8  318.0 150  2.76  3.520 16.87  0  0    3    2
# AMC Javelin       15.2   8  304.0 150  3.15  3.435 17.30  0  0    3    2
# Camaro Z28        13.3   8  350.0 245  3.73  3.840 15.41  0  0    3    4
# Pontiac Firebird  19.2   8  400.0 175  3.08  3.845 17.05  0  0    3    2
# Ford Pantera L    15.8   8  351.0 264  4.22  3.170 14.50  0  1    5    4
# Maserati Bora     15.0   8  301.0 335  3.54  3.570 14.60  0  1    5    8
```

(e) In addition to the previous selection, also select the car models that either have more than 3 carburetors or weigh less than 3500 lbs. How many car models satisfy these conditions?

Answer

```
# Use the Boolean operator '|' (logical OR).
# Note that the weight is specified per 1000 lbs (see ?mtcars)
mtcars[(mtcars$mpg < 22) & (mtcars$cyl > 6) & ((mtcars$carb > 3) | (mtcars$wt < 3.5)), ]

#           mpg cyl  disp  hp  drat   wt  qsec vs  am  gear  carb
# Hornet Sportabout  18.7   8  360 175  3.15  3.440 17.02  0  0    3    2
# Duster 360        14.3   8  360 245  3.21  3.570 15.84  0  0    3    4
# Cadillac Fleetwood 10.4   8  472 205  2.93  5.250 17.98  0  0    3    4
# Lincoln Continental 10.4   8  460 215  3.00  5.424 17.82  0  0    3    4
# Chrysler Imperial 14.7   8  440 230  3.23  5.345 17.42  0  0    3    4
# AMC Javelin       15.2   8  304 150  3.15  3.435 17.30  0  0    3    2
# Camaro Z28        13.3   8  350 245  3.73  3.840 15.41  0  0    3    4
# Ford Pantera L    15.8   8  351 264  4.22  3.170 14.50  0  1    5    4
# Maserati Bora     15.0   8  301 335  3.54  3.570 14.60  0  1    5    8

# The number of car models is the number of rows, that is the first dimension
dim(mtcars[(mtcars$mpg < 22) & (mtcars$cyl > 6) & ((mtcars$carb > 3) | (mtcars$wt < 3.5)), ])

# [1] 9 11

# The number of rows can also be retrieved with 'nrow'
nrow(mtcars[(mtcars$mpg < 22) & (mtcars$cyl > 6) & ((mtcars$carb > 3) | (mtcars$wt < 3.5)), ])

# [1] 9
```

(f) The variable `am` is a numeric variable that indicates the type of transmission:

- 0: automatic
- 1: manual

Add a variable called `am_char` to the `mtcars` data set where you recode the variable `am` and replace 0 by “automatic” and 1 by “manual”.

Answer

```
mtcars$am_char[mtcars$am == 0] <- "automatic"
mtcars$am_char[mtcars$am == 1] <- "manual"
mtcars[,c("am", "am_char")]
```

```
#           am  am_char
# Mazda RX4          1  manual
# Mazda RX4 Wag      1  manual
# Datsun 710          1  manual
# Hornet 4 Drive     0 automatic
# Hornet Sportabout  0 automatic
# Valiant            0 automatic
# Duster 360         0 automatic
# Merc 240D          0 automatic
# Merc 230           0 automatic
# Merc 280           0 automatic
# Merc 280C          0 automatic
# Merc 450SE         0 automatic
# Merc 450SL         0 automatic
# Merc 450SLC        0 automatic
# Cadillac Fleetwood 0 automatic
# Lincoln Continental 0 automatic
# Chrysler Imperial  0 automatic
# Fiat 128           1  manual
# Honda Civic        1  manual
# Toyota Corolla     1  manual
# Toyota Corona     0 automatic
# Dodge Challenger   0 automatic
# AMC Javelin        0 automatic
# Camaro Z28         0 automatic
# Pontiac Firebird   0 automatic
# Fiat X1-9          1  manual
# Porsche 914-2      1  manual
# Lotus Europa       1  manual
# Ford Pantera L     1  manual
# Ferrari Dino       1  manual
# Maserati Bora      1  manual
# Volvo 142E         1  manual
```

We will work with a data set that gives the survival status of passengers on the Titanic. See [here](#) for a description of the variables. Some background information on the data can be found on [titanic.html](#).

Question 7. (a) Download the `titanic` data set `titanic3.dta` in STATA format from the [course website](#) and import it into R using the function `read.dta`. Do not use the function `read_dta` from the `haven` package nor the ‘Import Dataset’ option in RStudio. This leads to slight differences in the imported data which may lead to problems in some of the exercises. Give the data set an appropriate name as an R object. E.g., we can call it `titanic3` (but feel free to give it another name). Before importing the data, you first have to load

the **foreign** package in which the function `read.dta` is defined. Moreover, you probably will need to point R to the right folder where you saved the file `titanic3.dta`. You can do this by changing the so-called *working directory*, which will be explained later. Using the basic R environment you can do this via the menu (**File - Change dir**), and similarly for RStudio (**Session - Set Working Directory - Choose Directory**).

Answer

```
library(foreign)
titanic3 <- read.dta("titanic3.dta", convert.underscore=TRUE)
```

We take a look at the values in the `titanic` data set.

(b) First, make the whole data set visible in a spreadsheet like format (how this is done depends on whether base R or RStudio is used).

Answer

This can be done using **View** on the command line. You can also use the menu: in R use **Edit - Data editor**, in RStudio click on the name of the data set in the **Environment** window.

(c) Often, it is sufficient to show a few records of the total data set. This can be done via selections on the rows, but another option is to use the functions `head` and `tail`. Use these functions to inspect the first 4 and last 4 records (instead of 6 which is the default).

Answer

```
head(titanic3, n = 4)
```

#	pclass	survived	name	sex	age	sibsp	parch
# 1	1st	1	Allen, Miss. Elisabeth Walton	female	29.0000	0	0
# 2	1st	1	Allison, Master. Hudson Trevor	male	0.9167	1	2
# 3	1st	0	Allison, Miss. Helen Loraine	female	2.0000	1	2
# 4	1st	0	Allison, Mr. Hudson Joshua Crei	male	30.0000	1	2

```

#   ticket   fare  cabin  embarked boat body             home.dest
# 1  24160 211.3375    B5 Southampton    2  NA                St Louis, MO
# 2 113781 151.5500 C22 C26 Southampton   11  NA Montreal, PQ / Chesterville, ON
# 3 113781 151.5500 C22 C26 Southampton    NA Montreal, PQ / Chesterville, ON
# 4 113781 151.5500 C22 C26 Southampton   135 Montreal, PQ / Chesterville, ON
#   dob family agecat
# 1 -28019.25   no (18,30]
# 2 -17761.82  yes (0,18]
# 3 -18157.50  yes (0,18]
# 4 -28384.50  yes (18,30]

tail(titanic3, n = 4)
```

#	pclass	survived	name	sex	age	sibsp	parch	ticket
# 1306	3rd	0	Zabour, Miss. Thamine	female	NA	1	0	2665
# 1307	3rd	0	Zakarian, Mr. Mapriededer	male	26.5	0	0	2656
# 1308	3rd	0	Zakarian, Mr. Ortin	male	27.0	0	0	2670
# 1309	3rd	0	Zimmerman, Mr. Leo	male	29.0	0	0	315082

```

#   fare cabin  embarked boat body home.dest   dob family agecat
# 1306 14.4542  Cherbourg    NA                NA   yes  <NA>
# 1307  7.2250  Cherbourg    304             -27106.12  no (18,30]
# 1308  7.2250  Cherbourg    NA             -27288.75  no (18,30]
```

```
# 1309 7.8750 Southampton NA -28019.25 no (18,30]
```

The function `dim` can be used to find the number of rows (passengers in this case) and columns (variables) in the data.

```
dim(titanic3)
```

An alternative is the function `str`. This function shows information per column (type of variable, first records, levels in case of factor variables) as well as the total number of rows and columns.

```
str(titanic3)
```

(d) Issue both commands and study the output.

Answer

```
dim(titanic3)
```

```
# [1] 1309 17
```

(e) Summarize the data set by using the `summary` function.

Answer

```
# Here the summary is shown for four of the variables only  
summary(titanic3[,c("survived", "pclass", "home.dest", "dob")])
```

```
# survived pclass home.dest dob  
# Min. :0.000 1st:323 Length:1309 Min. :-46647  
# 1st Qu.:0.000 2nd:277 Class :character 1st Qu.:-31672  
# Median :0.000 3rd:709 Mode :character Median :-27654  
# Mean :0.382 Mean :-28341  
# 3rd Qu.:1.000 3rd Qu.:-25097  
# Max. :1.000 Max. :-17488  
# NA's :263
```

This gives a summary of all the variables in the data set. We can see that for categorical variables like `pclass` a frequency distribution is given, whereas for continuous variables like `age` numerical summaries are given. Still, for some variables we do not automatically get what we would like or expect:

- The variable `survived` is dichotomous with values zero and one, which are interpreted as numbers.
- The categorical variable `pclass` is represented differently from the categorical variable `home.dest`.
- The variable `dob`, which gives the date of birth, is represented by large negative numbers.

In subsequent exercises, we will shed further light on these anomalies and we will try to repair some of these.

Question 8. We can also summarize specific columns (variables) of a `data.frame`. There are many ways to summarize a variable, depending on its structure and variability. For continuous variables, the same `summary` function can be used, but other options are the functions `mean`, `quantile`, `IQR`, `sd` and `var`. For categorical summaries, one may use `summary` and `table`. Note that missing values are treated differently depending on the function used.

(a) Summarize the age variable in the `titanic` data set (the age column is selected via `titanic3$age`). Give the 5%, 25%, 50%, 75% and 95% quantiles and the inter-quartile range. You may have to take a look at the help files for the functions.

Answer

```

# Note that you have to convert percentages into probabilities
quantile(titanic3$age, probs=c(0.05,0.25,0.5,0.75,0.95), na.rm=TRUE)

# 5% 25% 50% 75% 95%
# 5 21 28 39 57

IQR(titanic3$age, na.rm=TRUE)

# [1] 18

```

(b) Summarize the `survived` variable using the `table` function. Also give a two-by-two table for `sex` and survival status using the same `table` function.

Answer

```

table(titanic3$survived)

#
# 0 1
# 809 500

table(titanic3$sex, titanic3$survived)

#
#           0  1
# female 127 339
# male   682 161

```

Question 9 (OPTIONAL).

Instead of the file in STATA format, we also made available part of the `titanic` data set in tab-delimited format (`titanic3select.txt`). Download this file from the [course website](#) and then import it using the command `read.table`. Note that this file has been manipulated in Excel and that importing the data is not as straightforward as you would have hoped. You will need to tweak the arguments of `read.table` and/or make some changes to the file manually.

Answer

Running the following line of code:

```
titanic3.select <- read.table("titanic3select.txt",sep="\t",header=TRUE)
```

throws an error message:

```
Error in scan(file = file, what = what, sep = sep, quote = quote, dec = dec, :  
line 16 did not have 18 elements Error during wrapup: cannot open the connection
```

This error message can in principle be corrected by adding the argument `fill=TRUE`, which adds blank fields if rows have unequal length. However, running

```
titanic3.select <- read.table("titanic3select.txt",sep="\t",header=TRUE,fill=TRUE)
```

throws a warning message:

```
Warning message: In scan(file = file, what = what, sep = sep, quote = quote, dec =  
dec, : EOF within quoted string
```

It turns out that the data was not correctly imported, which is often easily diagnosed by inspecting the dimensions:

```
dim(titanic3.select)
```

Indeed the number of rows is 25 instead of the expected 30. This is caused by a trailing ' at row 25 for variable `home_dest`. This can be corrected by changing the default set of quoting characters:

```
titanic3.select <- read.table("titanic3select.txt", sep="\t", header=TRUE, fill=TRUE, quote="\")
```

A closer inspection of the data shows that the last column only contains NAs caused by trailing spaces. On the course website there is a [corrected version](#) of the file where the last column and the trailing ' at row 25 were deleted.

```
titanic3.select <- read.table("titanic3select_corrected.txt", sep="\t", header=TRUE)
```

Question 10. We have a further look at the output from the `summary` function, which was not always what we would like to see. First, give the commands (`sapply` will be explained later):

```
sapply(titanic3, mode)
```

```
#   pclass  survived      name      sex      age      sibsp
# "numeric" "numeric" "character" "numeric" "numeric" "numeric"
#   parch   ticket      fare      cabin  embarked      boat
# "numeric" "character" "numeric" "numeric" "numeric" "numeric"
#   body  home.dest      dob      family  agecat
# "numeric" "character" "numeric" "numeric" "numeric"
```

```
sapply(titanic3, is.factor)
```

```
#   pclass  survived      name      sex      age      sibsp      parch      ticket
#   TRUE    FALSE     FALSE     TRUE    FALSE    FALSE    FALSE    FALSE
#   fare    cabin  embarked      boat      body  home.dest      dob      family
#   FALSE    TRUE     TRUE     TRUE    FALSE    FALSE    FALSE    TRUE
#   agecat
#   TRUE
```

We see that `survived` has mode “numeric” and is not a factor (`is.factor(titanic3$survived)` gives `FALSE`). It is interpreted in the same way as the truly continuous variable `age`.

(a) Add a variable `status` to the `titanic` data set, which gives the survival status of the passengers as a factor variable with labels “no” and “yes” describing whether individuals survived. Make the value “no” the first level.

Answer

```
# Survival (0 = No; 1 = Yes)
titanic3$status <- factor(titanic3$survived, labels=c("no", "yes"))
```

(b) Variable `pclass` has mode “numeric” and is a factor, whereas `home.dest` has mode “character” and is not a factor. Give the commands

```
as.numeric(head(titanic3$pclass))
as.numeric(head(titanic3$home.dest))
```

and explain the difference in output.

Answer

```
as.numeric(head(titanic3$pclass))
# [1] 1 1 1 1 1 1
```

```
as.numeric(head(titanic3$home.dest))
```

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

We do not change the variables in this dataset that have mode “character”. They are variables that have many different values, and there is no reason to convert them into factors.

Question 11. (a) Take a look at the name (name), and the home town/destination (home.dest) of all passengers who were older than 70 years. Use the appropriate selection functions.

Answer

```
# Note that the function 'subset' also leaves out the passengers for which the  
# variable 'age' is missing
```

```
subset(titanic3,age>70)[,c("name","home.dest")]
```

```
#           name           home.dest  
# 10   Artagaveytia, Mr. Ramon   Montevideo, Uruguay  
# 15   Barkworth, Mr. Algernon Henry W   Hessle, Yorks  
# 62   Cavendish, Mrs. Tyrell William Little Onn Hall, Staffs  
# 136  Goldschmidt, Mr. George B   New York, NY  
# 728  Connors, Mr. Patrick  
# 1236 Svensson, Mr. Johan
```

```
# Another solution is
```

```
subset(titanic3,age>70,select=c(name,home.dest))
```

```
#           name           home.dest  
# 10   Artagaveytia, Mr. Ramon   Montevideo, Uruguay  
# 15   Barkworth, Mr. Algernon Henry W   Hessle, Yorks  
# 62   Cavendish, Mrs. Tyrell William Little Onn Hall, Staffs  
# 136  Goldschmidt, Mr. George B   New York, NY  
# 728  Connors, Mr. Patrick  
# 1236 Svensson, Mr. Johan
```

```
# Yet another solution is
```

```
titanic3[titanic3$age>70 & !is.na(titanic3$age),c("name","home.dest")]
```

```
#           name           home.dest  
# 10   Artagaveytia, Mr. Ramon   Montevideo, Uruguay  
# 15   Barkworth, Mr. Algernon Henry W   Hessle, Yorks  
# 62   Cavendish, Mrs. Tyrell William Little Onn Hall, Staffs  
# 136  Goldschmidt, Mr. George B   New York, NY  
# 728  Connors, Mr. Patrick  
# 1236 Svensson, Mr. Johan
```

(b) There is one person from Uruguay in this group. Select the single record from that person. Did this person travel with relatives?

Answer

```
subset(titanic3, name=="Artagaveytia, Mr. Ramon")
```

```
#   pclass survived           name sex age sibsp parch  ticket  
# 10    1st         0 Artagaveytia, Mr. Ramon male 71 0 0 PC 17609  
#   fare cabin embarked boat body           home.dest      dob family
```



```
# 10 49.5042      Cherbourg      22 Montevideo, Uruguay -43359.75      no
#      agecat status
# 10 (40,80]      no
# No he didn't travel with relatives, since the variable 'family' is 'no'
```

(c) Make a table of survivor status by sex, but only for the first class passengers. Use the `xtabs` function.

Answer

```
xtabs(~sex+status, data=titanic3, subset=(pclass=="1st"))

#      status
# sex      no yes
# female   5 139
# male    118  61
```

5 Graphics

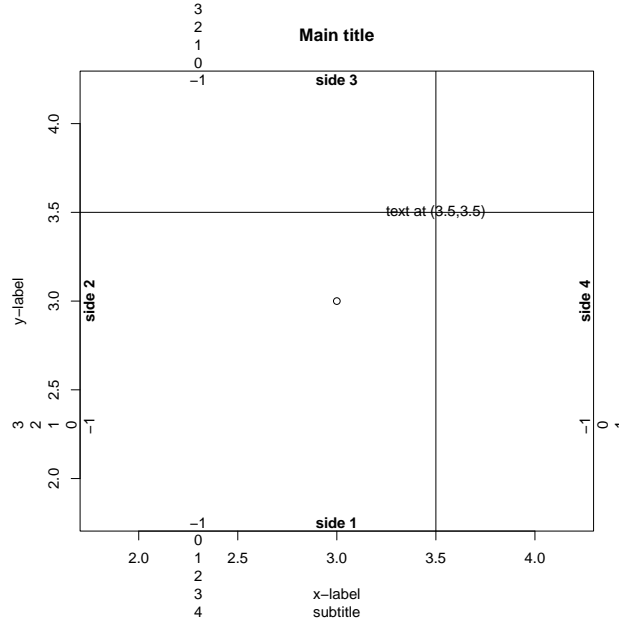
5.1 Basic graphics

The graphics subsystem of R offers a very flexible toolbox for high-quality graphing. There are typically three steps to producing useful graphics:

- Creating the basic plot
- Enhancing the plot with labels, legends, colors *etc.*
- Exporting the plot from R for use elsewhere

In the graphics model that R uses, a figure region consists of a central plotting region surrounded by margins. The basic graphics command is `plot`. The following piece of code illustrates the most common options:

```
plot(3,3,main="Main title",sub="subtitle",xlab="x-label",ylab="y-label")
text(3.5,3.5,"text at (3.5,3.5)")
abline(h=3.5,v=3.5)
for (side in 1:4) mtext(-1:4,side=side,at=2.3,line=-1:4)
mtext(paste("side",1:4),side=1:4,line=-1,font=2)
```



In this figure one can see that

- Sides are labelled clockwise starting with x -axis
- Coordinates in the margins are specified in *lines of text*
- Default margins are not all wide enough to hold all numbers $-1, \dots, 4$

You might want to use the `help` function to investigate some of the other functions and options.

Plots can be further finetuned with the `par` function. For instance, the default margin sizes can be changed using `par`. The default settings are

```
par("mar")
```

```
# [1] 5.1 4.1 4.1 2.1
```

This explains why only side 1 in the figure had a wide enough margin. This can be remedied by setting

```
par(mar=c(5,5,5,5))
```

before plotting the figure.

Question 12. (a) Try making this figure yourself by executing the code shown above.

(b) Save the figure you just made to a file. For this you have to know that R sends graphics to a *device*. The default device on most operating systems is the screen, for example the “Plots” window in RStudio. Saving a figure, therefore, requires changing R’s current device. See `help(device)` for the options. Save the figure you just made to a `png` and a `pdf` file. Don’t forget to close the device afterwards.

Answer

```
png(file="figure.png")
# Add code here to plot the figure (including par(mar=c(5,5,5,5)))
dev.off()
pdf(file="figure.pdf")
# Add code here to plot the figure (including par(mar=c(5,5,5,5)))
dev.off()
```

(c) When saving a figure to file, default values for the figure size are used. Save the figure to a pdf file with width and height of 21 inches.

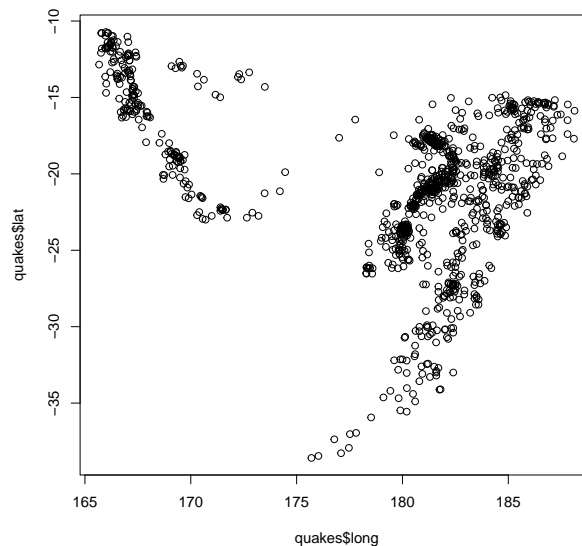
Answer

```
pdf(file="figureLarge.pdf",width=21,height=21)
# Add code here to plot the figure (including par(mar=c(5,5,5,5)))
dev.off()
```

Question 13. The quakes data set gives location and severity of earthquakes off Fuji. First load the data:

```
data(quakes)
```

(a) Make a scatterplot of latitude versus longitude. You should obtain a graph similar to:



Answer

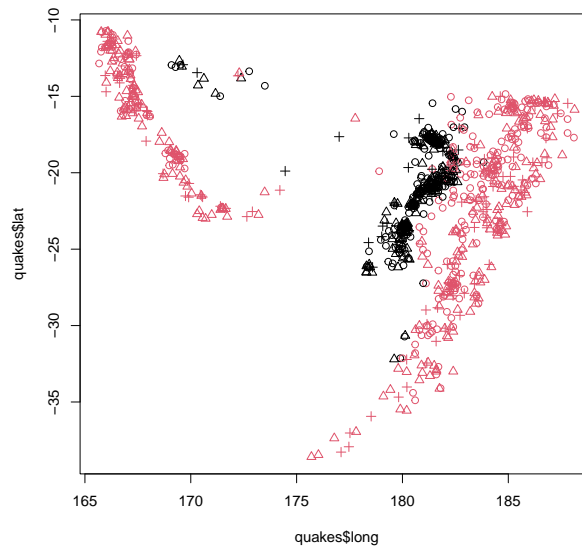
```
plot(quakes$long, quakes$lat)
```

(b) Use `cut` to divide the magnitude of quakes into three categories (cutoffs at 4.5 and 5) and use `ifelse` to divide depth into two categories (cutoff at 400). Hint: have a careful look at the (admittedly complicated) help page of `cut`, in particular the arguments `breaks` and `include.lowest`.

Answer

```
mag.cat <- with(quakes,cut(mag, breaks = c(4, 4.5, 5, 7),
                          include.lowest = TRUE ))
# More generic using the functions 'min' and 'max' that return the
# minimum and maximum, respectively, of a vector
mag.cat <- with(quakes,cut(mag, breaks = c(min(mag), 4.5, 5, max(mag)),
                          include.lowest = TRUE ))
levels(mag.cat) <- c("low", "medium", "high")
depth.cat <- factor(ifelse(quakes$depth>400, "deep", "shallow"))
```

(c) Redraw the plot, with symbols by magnitude and colors by depth. You should obtain a graph similar to:



Answer

*# Note that for 'col' the factor 'depth.cat' is interpreted as numeric (deep=1 and
shallow=2) and that the first two colours of palette() are used. Strangely enough
for 'pch' this is not the case and the factor 'mag.cat' has to be converted to a
numeric vector using the function 'as.numeric'.*

```
plot(quakes$long, quakes$lat, pch=as.numeric(mag.cat), col=depth.cat)
```

(d) The magnitude of the earthquakes is given in Richter scale. Calculate the energy released in each earthquake as $10^{(3/2)}$ to the power of the Richter magnitude.

Answer

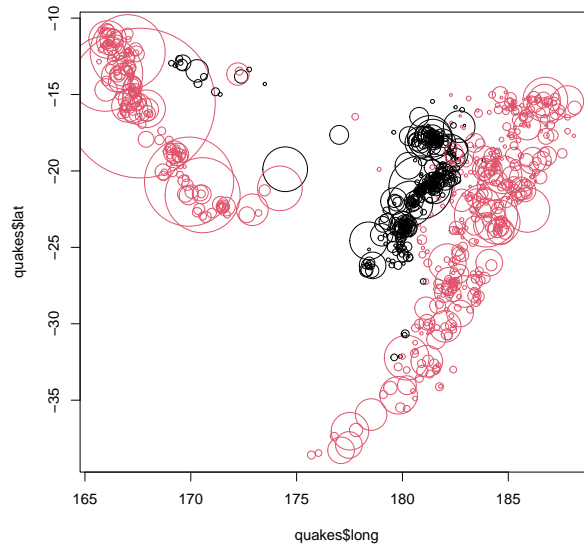
```
energy <- (10^(3/2))^quakes$mag
```

(e) The `cex` argument of `plot` can be used to scale the plot symbols. We will scale the plot symbols so that the surface of the plot symbol is proportional to the released energy. Calculate plot symbol size as the square root of the energy divided by the median square root of the energy (to get median symbol size 1).

Answer

```
symbolsize <- sqrt(energy)/median(sqrt(energy))
```

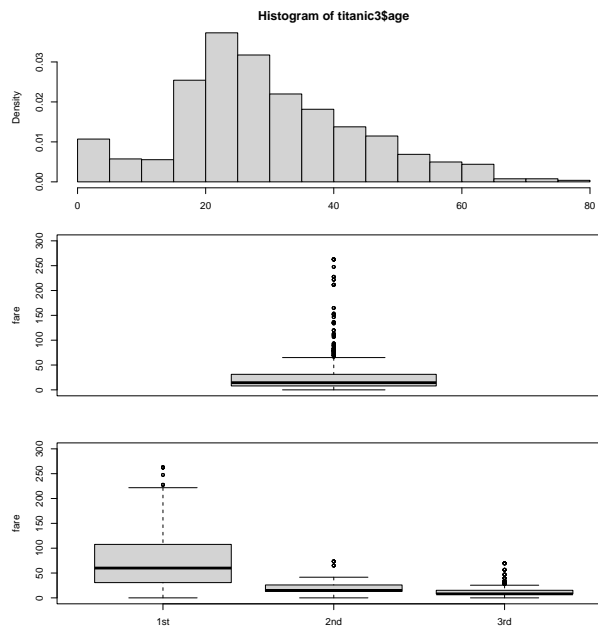
(f) Plot the magnitude of earthquakes again, but with plot symbols sized by energy. Keep the coloring by depth. You should obtain a graph similar to:



Answer

```
plot(quakes$long, quakes$lat, cex=symbolsize, col=depth.cat)
```

Question 14. Different plots can be combined in a single window (device) via , e.g., `par(mfrow=c(...))` or `layout(...)`. Combine the histogram and the two boxplots for the `titanic` data from the lecture into a single plot. Find a nice layout of your final plot, see help files for setting proper margins, etc. You should obtain a graph similar to:



Answer

```

par(mfrow=c(3,1))
# Make the margins smaller than default
par(mar=c(2,4,2,2))
hist(titanic3$age,breaks=15,freq=FALSE)
boxplot(titanic3$fare,ylim=c(0,300),ylab="fare")
plot(fare~pclass,data=titanic3,ylim=c(0,300),ylab="fare")

```

6 Structure of R

Question 15. Investigate which environments are in the search path. Take a look at the objects that exist in the workspace. Which is the current working directory?

Answer

```

# You will get different results depending on your configuration
search()

# [1] ".GlobalEnv"      "package:foreign"  "package:stats"
# [4] "package:graphics" "package:grDevices" "package:utils"
# [7] "package:datasets" "package:methods"  "Autoloads"
# [10] "package:base"

ls()

# [1] "curr"              "denominator"
# [3] "depth.cat"        "energy"
# [5] "exrate"           "index"
# [7] "islands"          "islands.more20"
# [9] "islands.names"    "islands.withoutMoluccas"
# [11] "M"                "mag.cat"
# [13] "mtcars"           "notMoluccas"
# [15] "numerator"        "quakes"
# [17] "side"             "symbolsize"
# [19] "titanic3"         "vec"
# [21] "vowels"           "xmean"
# [23] "xstd"

getwd()

# [1] "C:/Users/P075846/Dropbox/Education/Computing in R/Exercises"

```

Question 16. The function `mean` is defined in the `base` package, which is included in the search path at startup. From the `search` command, we can see where in the search path the `base` package is located. Issue the command

```
ls("package:base", pattern="mean")
```

Instead of the argument `package:base`, we could have given the position in the search path of the `base` package (that is `ls(10, pa="mean")` if `base` is in position 10). Have a look at the different names of the `mean` function.

Question 17. Save the `titanic` data set in R binary format with extension “.RData”.

Answer

```
save(titanic3, file="Titanic.RData")
```

7 Data manipulation

Question 18. Sort the `titanic` data set according to the age of the passengers and store the result in a separate object, e.g. named `data.sorted`. Have a look at the 10 youngest and the 10 oldest individuals. For reasons of space, restrict to the first 5 columns when showing the results. What do you notice with respect to passenger class and age?

Answer

```
# If not installed yet, first install the package dplyr that contains the function  
# arrange  
#install.packages("dplyr")  
library(dplyr)  
data.sorted <- arrange(titanic3, age)  
head(data.sorted[,1:5],10)
```

#	pclass	survived	name	sex	age
# 764	3rd	1	Dean, Miss. Elizabeth Gladys \\\"M	female	0.1667
# 748	3rd	0	Danbom, Master. Gilbert Sigvard	male	0.3333
# 1241	3rd	1	Thomas, Master. Assad Alexander	male	0.4167
# 428	2nd	1	Hamalainen, Master. Viljo	male	0.6667
# 658	3rd	1	Baclini, Miss. Eugenie	female	0.7500
# 659	3rd	1	Baclini, Miss. Helene Barbara	female	0.7500
# 1112	3rd	0	Peacock, Master. Alfred Edward	male	0.7500
# 360	2nd	1	Caldwell, Master. Alden Gates	male	0.8333
# 549	2nd	1	Richards, Master. George Sibley	male	0.8333
# 612	3rd	1	Aks, Master. Philip Frank	male	0.8333

```
# Use is.na to exclude the passengers for whom 'age' is missing  
tail(subset(data.sorted,!is.na(age))[,1:5],10)
```

#	pclass	survived	name	sex	age
# 595	2nd	0	Wheadon, Mr. Edward H	male	66.0
# 286	1st	0	Straus, Mr. Isidor	male	67.0
# 82	1st	0	Crosby, Capt. Edward Gifford	male	70.0
# 507	2nd	0	Mitchell, Mr. Henry Michael	male	70.0
# 728	3rd	0	Connors, Mr. Patrick	male	70.5
# 10	1st	0	Artagaveytia, Mr. Ramon	male	71.0
# 136	1st	0	Goldschmidt, Mr. George B	male	71.0
# 1236	3rd	0	Svensson, Mr. Johan	male	74.0
# 62	1st	1	Cavendish, Mrs. Tyrell William	female	76.0
# 15	1st	1	Barkworth, Mr. Algernon Henry W	male	80.0

Question 19. Give a summary of the fare paid for the three passenger classes separately, using the `summary` function, the `subset` function for selecting the appropriate rows, as well as one of the mechanisms for selecting columns.

Answer

```
summary(subset(titanic3, pclass=="1st")$fare)
```

```

#   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
#   0.00  30.70   60.00   87.51 107.66  512.33
summary(subset(titanic3, pclass=="2nd")$fare)

#   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
#   0.00  13.00   15.05   21.18  26.00   73.50
summary(subset(titanic3, pclass=="3rd")$fare)

#   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.    NA's
#   0.00   7.75   8.05   13.30  15.25   69.55     1

```

Remark

Instead of writing three lines of code, applying the `summary` function to each of the three subsets, we could write a `for` loop. When using a `for` loop, we need to explicitly write the `print` command:

```
for(i in 1:3){print(summary(subset(titanic3, pclass==levels(pclass)[i])$fare))}
```

The function `aggregate` is yet another option:

```
aggregate(fare~pclass,data=titanic3,FUN=summary)
```

Later, we will see even more efficient ways.

Question 20. Create an extra variable that categorizes the variable `sibsp` (the number of siblings/spouses aboard) into three groups: 0, 1 and more than 1. Also, create an extra factor variable named `paid`, which shows whether the individual paid for the trip (i.e. whether `fare > 0`). Preferably, use the `within` or the `transform` function. Check whether the results are correct.

Answer

```

titanic3 <- within(titanic3, {
  sibspcat <- cut(sibsp, breaks=c(0,1,2,9),include.lowest=TRUE,
                right=FALSE, labels=c("0","1","2-8"))
  paid <- factor(fare>0, labels=c("no","yes"))
})

titanic3 <- transform(titanic3,
  sibspcat = cut(sibsp, breaks=c(0,1,2,9),include.lowest=TRUE,
                right=FALSE, labels=c("0","1","2-8")),
  paid = factor(fare>0, labels=c("no","yes"))
)

```

8 Documentation and help

Question 21. R is also very flexible with respect to manipulation of character data, such as words. In this exercise, you will see an example.

(a) Create a character vector of length three that consists of the words “Academic”, “Medical” and “Center”. Give the object the name `AMC`. Check the *mode* of the object.

Answer


```

AMC <- c("Academic","Medical","Center") # a character vector named AMC
mode(AMC)

# [1] "character"
is.character(AMC)

# [1] TRUE

```

(b) Next, we want to abbreviate the word and obtain `AMC` as output. Try to find the appropriate functions using the commands

```

help.search("abbreviate")
help.search("combine")
help.search("quote")

```

Answer

```

#help(abbreviate)
abbreviate(AMC,1) # selects first character

# Academic Medical Center
#      "A"      "M"      "C"

#help(paste)
paste(abbreviate(AMC,1),collapse="") # gives AMC

# [1] "AMC"

```

Finally, if you want to remove the quotes give the following command

```

noquote(paste(abbreviate(AMC,1),collapse="")) # removes quotes

```

Question 22. Try to find more information on a topic of interest and how R can be of help. If you do not have any idea, you can search for the keyword “crosstab”.

Answer

```

help(crosstab)
help.search("crosstab")
RSiteSearch("crosstab")
install.packages("sos")
library(sos)
findFn("crosstab")

```

9 Statistical analysis

Question 23. Fit a linear model that predicts fare as a function of age. Since fare has a very skewed distribution, we use the transformed variable $\log_{10}(\text{fare}+1)$. Consider the following issues.

(a) Fit the model and store the results in an R object. Summarize the model using the `summary` function.

Answer

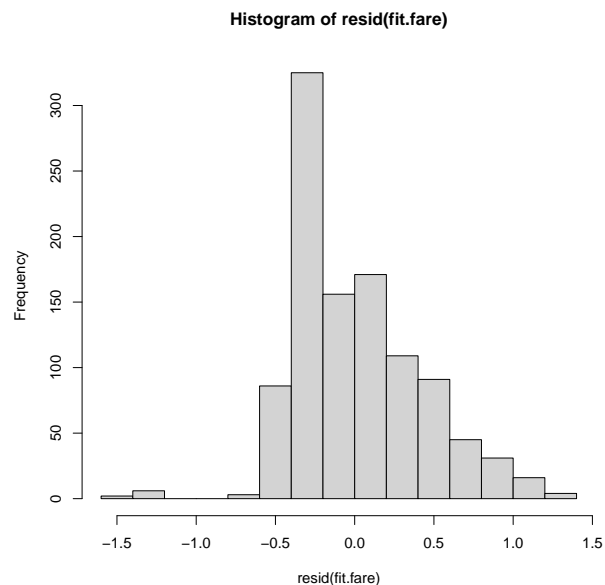
```

fit.fare <- lm(log10(fare+1) ~ age, data=titanic3)
summary(fit.fare)

#
# Call:
# lm(formula = log10(fare + 1) ~ age, data = titanic3)
#
# Residuals:
#      Min       1Q   Median       3Q      Max
# -1.44366 -0.33354 -0.07742  0.27298  1.34630
#
# Coefficients:
#              Estimate Std. Error t value Pr(>|t|)
# (Intercept) 1.1651838  0.0293881  39.648 < 2e-16 ***
# age          0.0056833  0.0008869   6.408 2.23e-10 ***
# ---
# Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
#
# Residual standard error: 0.4123 on 1043 degrees of freedom
# (264 observations deleted due to missingness)
# Multiple R-squared:  0.03788, Adjusted R-squared:  0.03696
# F-statistic: 41.06 on 1 and 1043 DF,  p-value: 2.228e-10

```

(b) One of the assumptions of a standard linear model is that the residuals have approximately normal distribution. Make a histogram of the residuals, using the functions `resid` and `hist`. You should obtain a graph similar to:



Answer

```

fit.fare <- lm(log10(fare+1) ~ age, data=titanic3)
hist(resid(fit.fare))

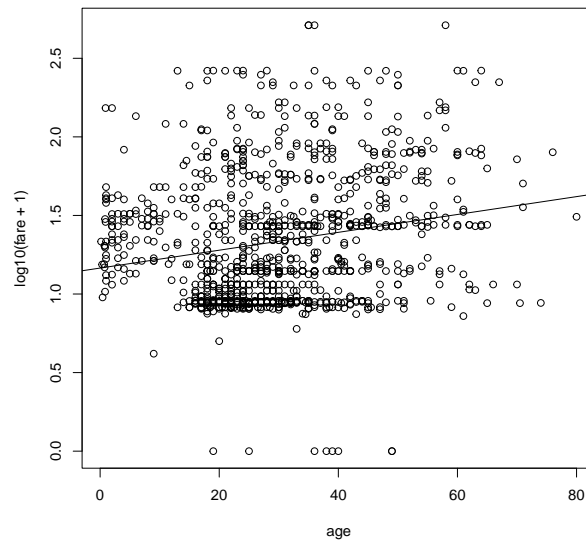
```

(c) Make a plot of the residuals against the fitted values, using (with `fit.fare` the name of the object that

contains the linear model fit):

```
plot(resid(fit.fare)~fitted(fit.fare))
```

(d) Make a scatterplot of fare against age and add the linear regression line. A fitted regression line is added to a plot via `abline(fit.fare)`. You should obtain a graph similar to:



Answer

```
plot(log10(fare+1)~age,data=titanic3)
abline(fit.fare)
```

(e) Does the object have a class? If so, which are the generic functions that have a method for this class?

Answer

```
class(fit.fare)
# [1] "lm"
methods(class="lm")
# [1] add1          alias          anova          case.names    coerce
# [6] confint       cooks.distance deviance      dfbeta        dfbetas
# [11] drop1         dummy.coef    effects       extractAIC    family
# [16] formula      hatvalues     influence     initialize    kappa
# [21] labels       logLik        model.frame   model.matrix  nobs
# [26] plot          predict        print         proj          qr
# [31] residuals    rstandard    rstudent      show          simulate
# [36] slotsFromS3  summary       variable.names vcov
# see '?methods' for accessing help and source code
```

10 Programming and ply functions

Functions from the `apply` family are convenient shorthands for repetitions.

Question 24. Use `apply` to calculate the mean of the variables `age`, `fare`, and `body` of `titanic3`.

Answer

```
apply(subset(titanic3,select=c("age","fare","body")),2,mean,na.rm=TRUE)

#      age      fare      body
# 29.88113 33.29548 160.80992
```

Question 25. The `chickwts` data describes chicken weights by feed type. First load the data:

```
data(chickwts)
```

(a) Calculate the mean weight for each feed type.

Answer

```
tapply(chickwts$weight, chickwts$feed, mean)

# casein horsebean linseed meatmeal soybean sunflower
# 323.5833 160.2000 218.7500 276.9091 246.4286 328.9167
```

(b) Count the number of chicks with weight over 300 grams,

Answer

```
sum(chickwts$weight > 300)

# [1] 26
```

Further abstraction of the R code is possible through *functions*. Functions lead to more compact code that is easier to understand and also avoid duplication of the same code over and over again.

```
name <- function(arg_1,arg_2, ...){
  expr
}
```

- `expr` is, in general, a grouped expression containing the arguments `arg_1`, `arg_2` ...
- A call to the function is of the form `name(expr_1,expr_2, ...)`
- The value of the expression `expr` is the value returned by the function

Question 26. (a) For the `chickwts` data, write a function that takes a vector `x` as input and returns the number of observations in `x` greater than 300.

Answer

```
greater300 <- function(x) {
  sum(x > 300)
}
```

(b) Calculate the number of chicks with weight over 300 grams for each feed type.

Answer

```
tapply(chickwts$weight, chickwts$feed, greater300)
```

```
# casein horsebean linseed meatmeal soybean sunflower  
#      8         0         1         5         3         9
```