

Outline

Mixed models in R using the lme4 package

Part 1: Introduction to R

Douglas Bates

University of Wisconsin - Madison
and R Development Core Team
<Douglas.Bates@R-project.org>

UseR!2009, Rennes, France
July 7, 2009

Web site and following the R code

Organizing data

Accessing and modifying variables

Subsets of data frames

Web sites associated with the tutorial

www.R-project.org Main web site for the R Project
cran.R-project.org Comprehensive R Archive Network primary site
cran.fr.R-project.org Main France mirror for CRAN
R-forge.R-project.org R-Forge, development site for many public R packages. This is also the URL of the repository for installing the development versions of the [lme4](#) and [Matrix](#) packages, if you are so inclined.
lme4.R-forge.R-project.org development site for the [lme4](#) package
lme4.R-forge.R-project.org/slides/2009-07-07-Rennes web site for this tutorial

Following the operations on the slides

- ▶ The lines of *R* code shown on these slides are available in files on the course web site. The file for this section is called [1Intro.R](#).
- ▶ If you open this file in the *R* application (the **File**→**Open** menu item or `<ctrl>-O`) and position the cursor at a particular line, then `<ctrl>-R` will send the line to the console window for execution and step to the next line.
- ▶ Any part of a line following a `#` symbol is a comment.
- ▶ The code is divided into named “chunks”, typically one chunk per slide that contains code.
- ▶ In the system called [Sweave](#) used to generate the slides the result of a call to a graphics function must be [printed](#). In interactive use this is not necessary but neither is it harmful.

Organizing data in R

- ▶ Standard rectangular data sets (columns are variables, rows are observations) are stored in *R* as *data frames*.
- ▶ The columns can be *numeric* variables (e.g. measurements or counts) or *factor* variables (categorical data) or *ordered* factor variables. These types are called the *class* of the variable.
- ▶ The `str` function provides a concise description of the structure of a data set (or any other class of object in *R*). The `summary` function summarizes each variable according to its class. Both are highly recommended for routine use.
- ▶ Entering just the name of the data frame causes it to be printed. For large data frames use the `head` and `tail` functions to view the first few or last few rows.

In-built data sets

- ▶ One of the packages attached by default to an *R* session is the `datasets` package that contains several data sets culled primarily from introductory statistics texts.
- ▶ We will use some of these data sets for illustration.
- ▶ The `Formaldehyde` data are from a calibration experiment, `Insectsprays` are from an experiment on the effectiveness of insecticides.
- ▶ Use `?` followed by the name of a function or data set to view its documentation. If the documentation contains an example section, you can execute it with the `example` function.

Data input

- ▶ The simplest way to input a rectangular data set is to save it as a comma-separated value (csv) file and read it with `read.csv`.
- ▶ The first argument to `read.csv` is the name of the file. On Windows it can be tricky to get the file path correct (backslashes need to be doubled). The best approach is to use the function `file.choose` which brings up a “chooser” panel through which you can select a particular file. The idiom to remember is

```
> mydata <- read.csv(file.choose())
```

for comma-separated value files or

```
> mydata <- read.delim(file.choose())
```

for files with tab-delimited data fields.
- ▶ If you are connected to the Internet you can use a URL (within quotes) as the first argument to `read.csv` or `read.delim`. (See question 1 in the first set of exercises)

The Formaldehyde data

```
> str(Formaldehyde)

'data.frame': 6 obs. of 2 variables:
 $ carb : num  0.1 0.3 0.5 0.6 0.7 0.9
 $ optden: num  0.086 0.269 0.446 0.538 0.626 0.782

> summary(Formaldehyde)

      carb      optden
Min.   :0.1000   Min.   :0.0860
1st Qu.:0.3500   1st Qu.:0.3132
Median :0.5500   Median :0.4920
Mean   :0.5167   Mean    :0.4578
3rd Qu.:0.6750   3rd Qu.:0.6040
Max.   :0.9000   Max.    :0.7820

> Formaldehyde

  carb optden
1  0.1  0.086
2  0.3  0.269
3  0.5  0.446
4  0.6  0.538
5  0.7  0.626
6  0.9  0.782
```

The InsectSprays data

```
> str(InsectSprays)

'data.frame': 72 obs. of 2 variables:
 $ count: num 10 7 20 14 14 12 10 23 17 20 ...
 $ spray: Factor w/ 6 levels "A","B","C","D",...: 1 1 1 1 1 1 1 1 1 1 ..

> summary(InsectSprays)

      count      spray
Min.   : 0.00   A:12
1st Qu.: 3.00   B:12
Median : 7.00   C:12
Mean   : 9.50   D:12
3rd Qu.:14.25   E:12
Max.   :26.00   F:12

> head(InsectSprays)

  count spray
1     10    A
2      7    A
3     20    A
4     14    A
5     14    A
6     12    A
```

Accessing and modifying variables

- ▶ The `$` operator is used to access variables within a data frame.

```
> Formaldehyde$carb
```

```
[1] 0.1 0.3 0.5 0.6 0.7 0.9
```

- ▶ You can also use `$` to assign to a variable name

```
> sprays$sqrtcount <- sqrt(sprays$count)
```

```
> names(sprays)
```

```
[1] "count"      "spray"      "sqrtcount"
```

- ▶ Assigning the special value `NULL` to the name of a variable removes it.

```
> sprays$sqrtcount <- NULL
```

```
> names(sprays)
```

```
[1] "count" "spray"
```

Copying, saving and restoring data objects

- ▶ Assigning a data object to a new name creates a copy.
- ▶ You can save a data object to a file, typically with the extension `.rda`, using the `save` function.
- ▶ To restore the object you load the file.

```
> sprays <- InsectSprays
```

```
> save(sprays, file = "sprays.rda")
```

```
> rm(sprays)
```

```
> ls.str()
```

```
> load("sprays.rda")
```

```
> names(sprays)
```

```
[1] "count" "spray"
```

Using with and within

- ▶ In complex expressions it can become tedious to repeatedly type the name of the data frame.
- ▶ The `with` function allows for direct access to variable names within an expression. It provides “read-only” access.

```
> Formaldehyde$carb * Formaldehyde$optden
```

```
[1] 0.0086 0.0807 0.2230 0.3228 0.4382 0.7038
```

```
> with(Formaldehyde, carb * optden)
```

```
[1] 0.0086 0.0807 0.2230 0.3228 0.4382 0.7038
```

- ▶ The `within` function provides read-write access to a data frame. It does not change the original frame; it returns a modified copy. To change the stored object you must assign the result to the name.

```
> sprays <- within(sprays, sqrtcount <- sqrt(count))
```

```
> str(sprays)
```

```
'data.frame': 72 obs. of 3 variables:
```

```
 $ count      : num 10 7 20 14 14 12 10 23 17 20 ...
```

```
 $ spray      : Factor w/ 6 levels "A","B","C","D",...: 1 1 1 1 1 1 1 1 1 1
```

```
 $ sqrtcount  : num 3.16 2.65 4.47 3.74 3.74 ...
```

Data Organization

- ▶ Careful consideration of the data layout for experimental or observational data is repaid in later ease of analysis. Sadly, the widespread use of spreadsheets does not encourage such careful consideration.
- ▶ If you are organizing data in a table, use consistent data types within columns. Databases require this; spreadsheets don't.
- ▶ A common practice in some disciplines is to convert categorical data to 0/1 “indicator variables” or to code the levels as numbers with a separate “data key”. This practice is unnecessary and error-inducing in *R*. When you see categorical variables coded as numeric variables, change them to factors or ordered factors.
- ▶ Spreadsheets also encourage the use of a “wide” data format, especially for longitudinal data. Each row corresponds to an experimental unit and multiple observation occasions are represented in different columns. The “long” format is preferred in *R*.

Subsets of data frames

- ▶ The `subset` function is used to extract a subset of the rows or of the columns or of both from a data frame.
- ▶ The first argument is the name of the data frame. The second is an expression indicating which rows are to be selected.
- ▶ This expression often uses logical operators such as `==`, the equality comparison, or `!=`, the inequality comparison, `>=`, meaning “greater than or equal to”, etc.

```
> str(sprayA <- subset(sprays, spray == "A"))
```

```
'data.frame': 12 obs. of 2 variables:
 $ count: num 10 7 20 14 14 12 10 23 17 20 ...
 $ spray: Factor w/ 6 levels "A","B","C","D",...: 1 1 1 1 1 1 1 1 1 1 1 1
```
- ▶ The optional argument `select` can be used to specify the variables to be included. There is an example of its use in question 4 of the first set of exercises.

Converting numeric variables to factors

- ▶ The `factor` (`ordered`) function creates a factor (ordered factor) from a vector. Factor labels can be specified in the optional `labels` argument.
- ▶ Suppose the `spray` variable in the `InsectSprays` data was stored as numeric values 1, 2, ..., 6. We convert it back to a factor with `factor`.

```
> str(sprays <- within(InsectSprays, spray <- as.integer(spray)))
'data.frame': 72 obs. of 2 variables:
 $ count: num 10 7 20 14 14 12 10 23 17 20 ...
 $ spray: int 1 1 1 1 1 1 1 1 1 1 ...

> str(sprays <- within(sprays, spray <- factor(spray,
+ labels = LETTERS[1:6])))
'data.frame': 72 obs. of 2 variables:
 $ count: num 10 7 20 14 14 12 10 23 17 20 ...
 $ spray: Factor w/ 6 levels "A","B","C","D",...: 1 1 1 1 1 1 1 1 1 1 ..
```

Subsets and factors

- ▶ The way that factors are defined, a subset of a factor retains the original set of levels. Usually this is harmless but sometimes it can cause unexpected results.
- ▶ You can “drop unused levels” by applying `factor` to the factor. Many functions, such as `xtabs`, which is used to create cross-tabulations, have optional arguments with names like `drop.unused.levels` to automate this.

```
> xtabs(~spray, sprayA)

spray
  A  B  C  D  E  F
12  0  0  0  0  0

> xtabs(~spray, sprayA, drop = TRUE)

spray
  A
12
```

Dropping unused levels in the spray factor and %in%

```
> str(sprayA <- within(sprayA, spray <- factor(spray)))
```

```
'data.frame': 12 obs. of 2 variables:  
 $ count: num 10 7 20 14 14 12 10 23 17 20 ...  
 $ spray: Factor w/ 1 level "A": 1 1 1 1 1 1 1 1 1 1 ...
```

```
> xtabs(~spray, sprayA)
```

```
spray  
 A  
12
```

- ▶ Another useful comparison operator is %in% for selecting a subset of the values in a variable.

```
> str(sprayDEF <- subset(sprays, spray %in% c("D", "E",  
+ "F")))
```

```
'data.frame': 36 obs. of 2 variables:  
 $ count: num 3 5 12 6 4 3 5 5 5 5 ...  
 $ spray: Factor w/ 6 levels "A","B","C","D",...: 4 4 4 4 4 4 4 4 4 4 ..
```

Using reshape

- ▶ The reshape function allows for more general translations of long to wide and vice-versa. It is specifically intended for longitudinal data.
- ▶ There is also a package called "reshape" with even more general (but potentially confusing) capabilities.
- ▶ Phil Spector's book, *Data Manipulation with R* (Springer, 2008) covers this topic in more detail.

"Long" and "wide" forms of data

- ▶ Spreadsheet users tend to store balanced data, such as InsectSprays, across many columns. This is called the "wide" format. The unstack function converts a simple "long" data set to wide; stack for the other way.
> str(unstack(InsectSprays))

```
'data.frame': 12 obs. of 6 variables:  
 $ A: num 10 7 20 14 14 12 10 23 17 20 ...  
 $ B: num 11 17 21 11 16 14 17 17 19 21 ...  
 $ C: num 0 1 7 2 3 1 2 1 3 0 ...  
 $ D: num 3 5 12 6 4 3 5 5 5 5 ...  
 $ E: num 3 5 3 5 3 6 1 1 3 2 ...  
 $ F: num 11 9 15 22 15 16 13 10 26 26 ...
```

- ▶ The problem with the wide format is that it only works for balanced data. A designed experiment may produce balanced data (although "Murphy's Law" would indicate otherwise) but observational data are rarely balanced.
- ▶ Stay with the long format (all the observations on all the units are in a single column) when possible.

Determining unique rows in a data frame

- ▶ One disadvantage of keeping data in the wide format is redundancy and the possibility of inconsistency.
- ▶ In the first set of exercises you are asked to create a data frame classroom from a csv file available on the Internet. Each of the 1190 rows corresponds to a student in a classroom in a school. There is one numeric "school level" covariate, housepov.
- ▶ To check if housepov is stored consistently we select the unique combinations of only those two columns

```
> str(unique(subset(classroom, select = c(schoolid, housepov))))
```

```
'data.frame': 107 obs. of 2 variables:  
 $ schoolid: Factor w/ 107 levels "1","2","3","4",...: 1 2 3 4 5 6 7 8 9  
 $ housepov: num 0.082 0.082 0.086 0.365 0.511 0.044 0.148 0.085 0.537
```