

The doBy package

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1 Introduction

The doBy package grew out of a need to calculate groupwise summary statistics in a simple way, much in the spirit of PROC SUMMARY of the SAS system. We have tried to keep the interface to the functions based on specifying formulas.

```
> library(doBy)

Hmisc library by Frank E Harrell Jr

Type library(help='Hmisc'), ?Overview, or ?Hmisc.Overview')
to see overall documentation.

NOTE:Hmisc no longer redefines [.factor to drop unused levels when
subsetting. To get the old behavior of Hmisc type dropUnusedLevels().
```

2 Data

2.1 CO2 data

The CO2 data frame comes from an experiment on the cold tolerance of the grass species *Echinochloa crus-galli*. To limit the amount of output we modify names and levels of variables as follows

```
> data(CO2)
> CO2 <- transform(CO2, Treat = Treatment, Treatment = NULL)
> levels(CO2$Treat) <- c("nchil", "chil")
> levels(CO2$Type) <- c("Que", "Mis")
> CO2 <- subset(CO2, Plant %in% c("Qn1", "Qc1", "Mn1", "Mc1"))
```

whereby the data becomes

```
> CO2

  Plant Type conc uptake Treat
1   Qn1  Que   95   16.0 nchil
2   Qn1  Que  175   30.4 nchil
3   Qn1  Que  250   34.8 nchil
4   Qn1  Que  350   37.2 nchil
5   Qn1  Que  500   35.3 nchil
6   Qn1  Que  675   39.2 nchil
7   Qn1  Que 1000   39.7 nchil
22  Qc1  Que   95   14.2 chil
23  Qc1  Que  175   24.1 chil
24  Qc1  Que  250   30.3 chil
25  Qc1  Que  350   34.6 chil
26  Qc1  Que  500   32.5 chil
27  Qc1  Que  675   35.4 chil
28  Qc1  Que 1000   38.7 chil
43  Mn1  Mis   95   10.6 nchil
44  Mn1  Mis  175   19.2 nchil
45  Mn1  Mis  250   26.2 nchil
46  Mn1  Mis  350   30.0 nchil
47  Mn1  Mis  500   30.9 nchil
48  Mn1  Mis  675   32.4 nchil
49  Mn1  Mis 1000   35.5 nchil
64  Mc1  Mis   95   10.5 chil
65  Mc1  Mis  175   14.9 chil
66  Mc1  Mis  250   18.1 chil
67  Mc1  Mis  350   18.9 chil
68  Mc1  Mis  500   19.5 chil
69  Mc1  Mis  675   22.2 chil
70  Mc1  Mis 1000   21.9 chil
```

2.2 Airquality data

The `airquality` dataset contains air quality measurements in New York, May to September 1973. The months are coded as 5, ..., 9. To limit the output we

only consider data for two months:

```
> airquality <- subset(airquality, Month %in% c(5, 6))
> head(airquality, n = 20)
```

	Ozone	Solar.R	Wind	Temp	Month	Day
1	41	190	7.4	67	5	1
2	36	118	8.0	72	5	2
3	12	149	12.6	74	5	3
4	18	313	11.5	62	5	4
5	NA	NA	14.3	56	5	5
6	28	NA	14.9	66	5	6
7	23	299	8.6	65	5	7
8	19	99	13.8	59	5	8
9	8	19	20.1	61	5	9
10	NA	194	8.6	69	5	10
11	7	NA	6.9	74	5	11
12	16	256	9.7	69	5	12
13	11	290	9.2	66	5	13
14	14	274	10.9	68	5	14
15	18	65	13.2	58	5	15
16	14	334	11.5	64	5	16
17	34	307	12.0	66	5	17
18	6	78	18.4	57	5	18
19	30	322	11.5	68	5	19
20	11	44	9.7	62	5	20

3 The summaryBy function

The `summaryBy` function is used for calculating quantities like “the mean and variance of x and y for each combination of two factors A and B ”. Examples are based on the `CO2` data.

3.1 Basic usage

For example, the mean, median and variance of `uptake` and `conc` for each value of `Plant` is obtained by:

```
> summaryBy(conc + uptake ~ Plant, data = CO2, FUN = function(x) {
+   c(m = mean(x), v = var(x))
+ })
```

	Plant	conc.m	conc.v	uptake.m	uptake.v
1	Qn1	435	100950	33.23	67.48
2	Qc1	435	100950	29.97	69.47
3	Mn1	435	100950	26.40	75.59
4	Mc1	435	100950	18.00	16.96

Defining the function to return named values as above is the recommended use of `summaryBy`. The function can also be defined outside the call to `summaryBy`:

```
> myfun1 <- function(x) {
+   c(m = mean(x), v = var(x))
+ }
> summaryBy(conc + uptake ~ Plant, data = CO2, FUN = myfun1)
```

If the result of the function(s) are not named, then the names in the output data in general become less intuitive:

```
> myfun2 <- function(x) {
+   c(mean(x), var(x))
+ }
> summaryBy(conc + uptake ~ Plant, data = CO2, FUN = myfun2)
```

	Plant	conc.myfun21	conc.myfun22	uptake.myfun21	uptake.myfun22
1	Qn1	435	100950	33.23	67.48
2	Qc1	435	100950	29.97	69.47
3	Mn1	435	100950	26.40	75.59
4	Mc1	435	100950	18.00	16.96

The postfix argument gives an alternative way of naming the output variables:

```
> summaryBy(conc + uptake ~ Plant, data = CO2, postfix = c("mymean",
+   "myvar"), FUN = myfun2)
```

	Plant	conc.myfun21	conc.myfun22	uptake.myfun21	uptake.myfun22
1	Qn1	435	100950	33.23	67.48
2	Qc1	435	100950	29.97	69.47
3	Mn1	435	100950	26.40	75.59
4	Mc1	435	100950	18.00	16.96

3.2 Using a list of functions

It is possible to apply a list of functions. A typical usage will be by invoking a list of predefined functions:

```
> summaryBy(uptake ~ Plant, data = CO2, FUN = c(mean, var, median))
```

	Plant	uptake.mean	uptake.var	uptake.median
1	Qn1	33.23	67.48	35.3
2	Qc1	29.97	69.47	32.5
3	Mn1	26.40	75.59	30.0
4	Mc1	18.00	16.96	18.9

Slightly more elaborate is

```
> mymed <- function(x) c(med = median(x))
> summaryBy(uptake ~ Plant, data = CO2, FUN = c(mean, var, myfun1,
+   myfun2))
```

	Plant	uptake.mean	uptake.var	uptake.m	uptake.v	uptake.myfun21	uptake.myfun22
1	Qn1	33.23	67.48	33.23	67.48	33.23	67.48
2	Qc1	29.97	69.47	29.97	69.47	29.97	69.47
3	Mn1	26.40	75.59	26.40	75.59	26.40	75.59
4	Mc1	18.00	16.96	18.00	16.96	18.00	16.96

The naming of the output variables determined from what the functions returns. The names of the last two columns above are imposed by `summaryBy` because `myfun2` does not return named values. Specifying `postfix=` overrides these names but when `FUN` is a list of functions, the new names are not very informative either:¹

```
> summaryBy(uptake ~ Plant, data = CO2, postfix = c("aa", "bb",
+   "cc"), FUN = c(mean, var, myfun1, myfun2))
```

	Plant	uptake.aa	uptake.bb	uptake.m	uptake.v	uptake.myfun21	uptake.myfun22
1	Qn1	33.23	67.48	33.23	67.48	33.23	67.48
2	Qc1	29.97	69.47	29.97	69.47	29.97	69.47
3	Mn1	26.40	75.59	26.40	75.59	26.40	75.59
4	Mc1	18.00	16.96	18.00	16.96	18.00	16.96

¹This may be improved on later.

3.3 Copying variables out with the id argument

To get the value of the `Type` and `Treat` in the first row of the groups (defined by the values of `Plant`) copied to the output dataframe we use the `id` argument: as:

```
> summaryBy(conc + uptake ~ Plant, data = CO2, FUN = function(x) {
+   c(m = mean(x), med = median(x), v = var(x))
+ }, id = ~Type + Treat)
```

	Plant	conc.m	conc.med	conc.v	uptake.m	uptake.med	uptake.v	Type	Treat
1	Qn1	435	350	100950	33.23	35.3	67.48	Que	nchil
2	Qc1	435	350	100950	29.97	32.5	69.47	Que	chil
3	Mn1	435	350	100950	26.40	30.0	75.59	Mis	nchil
4	Mc1	435	350	100950	18.00	18.9	16.96	Mis	chil

3.4 Statistics on functions of data

We may want to calculate the mean and variance for the logarithm of `uptake`, for `uptake+conc` (not likely to be a useful statistic) as well as for `uptake` and `conc`. This can be achieved as:

```
> summaryBy(log(uptake) + I(conc + uptake) + conc + uptake ~ Plant,
+   data = CO2, FUN = function(x) {
+     c(m = mean(x), v = var(x))
+   })
```

	Plant	log(uptake).m	log(uptake).v	conc+uptake.m	conc+uptake.v	conc.m	conc.v
1	Qn1	3.467	0.10168	468.2	104747	435	100950
2	Qc1	3.356	0.11873	465.0	105297	435	100950
3	Mn1	3.209	0.17928	461.4	105642	435	100950
4	Mc1	2.864	0.06874	453.0	103157	435	100950

	uptake.m	uptake.v
1	33.23	67.48
2	29.97	69.47
3	26.40	75.59
4	18.00	16.96

If one does not want output variables to contain parentheses then setting `p2d=TRUE` causes the parentheses to be replaced by dots (“.”).

```
> summaryBy(log(uptake) + I(conc + uptake) ~ Plant, data = CO2,
+   p2d = TRUE, FUN = function(x) {
+     c(m = mean(x), v = var(x))
+   })
```

	Plant	log.uptake..m	log.uptake..v	conc+uptake.m	conc+uptake.v
1	Qn1	3.467	0.10168	468.2	104747
2	Qc1	3.356	0.11873	465.0	105297
3	Mn1	3.209	0.17928	461.4	105642
4	Mc1	2.864	0.06874	453.0	103157

3.5 The dot (“.”) on the left hand side of a formula

It is possible to use the dot (“.”) on the left hand side of the formula. The dot means “all numerical variables which do not appear elsewhere” (i.e. on the right hand side of the formula and in the `id` statement):

```

> summaryBy(log(uptake) + I(conc + uptake) + . ~ Plant, data = CO2,
+ FUN = function(x) {
+   c(m = mean(x), v = var(x))
+ })

```

	Plant	log(uptake).m	log(uptake).v	conc+uptake.m	conc+uptake.v	conc.m	conc.v
1	Qn1	3.467	0.10168	468.2	104747	435	100950
2	Qc1	3.356	0.11873	465.0	105297	435	100950
3	Mn1	3.209	0.17928	461.4	105642	435	100950
4	Mc1	2.864	0.06874	453.0	103157	435	100950

```

uptake.m uptake.v
1 33.23 67.48
2 29.97 69.47
3 26.40 75.59
4 18.00 16.96

```

3.6 The dot (".") on the right hand side of a formula

The dot (".") can also be used on the right hand side of the formula where it refers to “all non-numerical variables which are not specified elsewhere”:

```

> summaryBy(log(uptake) ~ Plant + ., data = CO2, FUN = function(x) {
+   c(m = mean(x), v = var(x))
+ })

```

	Plant	Type	Treat	log(uptake).m	log(uptake).v
1	Qn1	Que	nchil	3.467	0.10168
2	Qc1	Que	chil	3.356	0.11873
3	Mn1	Mis	nchil	3.209	0.17928
4	Mc1	Mis	chil	2.864	0.06874

3.7 Using “1” on the right hand side of the formula

Using 1 on the right hand side means no grouping:

```

> summaryBy(log(uptake) ~ 1, data = CO2, FUN = function(x) {
+   c(m = mean(x), v = var(x))
+ })

```

	log(uptake).m	log(uptake).v
1	3.224	0.1577

3.8 Preserving names of variables using keep.names

If the function applied to data only returns one value, it is possible to force that the summary variables retain the original names by setting `keep.names=TRUE`. A typical use of this could be

```

> summaryBy(conc + uptake + log(uptake) ~ Plant, data = CO2, FUN = mean,
+   id = ~Type + Treat, keep.names = TRUE)

```

	Plant	conc	uptake	log(uptake)	Type	Treat
1	Qn1	435	33.23	3.467	Que	nchil
2	Qc1	435	29.97	3.356	Que	chil
3	Mn1	435	26.40	3.209	Mis	nchil
4	Mc1	435	18.00	2.864	Mis	chil

4 The orderBy function

Ordering (or sorting) a data frame is possible with the `orderBy` function. Suppose we want to order the rows of the `airquality` data by `Temp` and by `Month` (within `Temp`) and that the ordering should be decreasing. This can be achieved by:

```
> x <- orderBy(~Temp + Month, data = airquality, decreasing = T)
```

The first lines of the result are:

```
> head(x)
```

	Ozone	Solar.R	Wind	Temp	Month	Day
42	NA	259	10.9	93	6	11
43	NA	250	9.2	92	6	12
40	71	291	13.8	90	6	9
39	NA	273	6.9	87	6	8
41	39	323	11.5	87	6	10
36	NA	220	8.6	85	6	5

5 The splitBy function

Suppose we want to split the `airquality` data into a list of dataframes, e.g. one dataframe for each month. This can be achieved by:

```
> x <- splitBy(~Month, data = airquality)
```

Information about the grouping is stored as a dataframe in an attribute called `groupid`:

```
> attr(x, "groupid")
```

	Month
1	5
2	6

6 The sampleBy function

Suppose we want a random sample of 50 % of the observations from a dataframe. This can be achieved with:

```
> sampleBy(~1, frac = 0.5, data = airquality)
```

Suppose instead that we want a systematic sample of every fifth observation within each month. This is achieved with:

```
> sampleBy(~Month, frac = 0.2, data = airquality, systematic = T)
```

7 The subsetBy function

Suppose we want to take out those rows within each month for which the wind speed is larger than the mean wind speed (within the month). This is achieved by:

```
> subsetBy(~Month, subset = "Wind>mean(Wind)", data = airquality)
```

Note that the statement `"Wind>mean(Wind)"` is evaluated within each month.

8 The transformBy function

The `transformBy` function is analogous to the `transform` function except that it works within groups. For example:

```
> transformBy(~Month, data = airquality, minW = min(Wind), maxW = max(Wind),
+             chg = sum(range(Wind) * c(-1, 1)))
```

9 Miscellaneous

9.1 The esticon function

Consider a linear model which explains `Ozone` as a linear function of `Month` and `Wind`:

```
> data(airquality)
> airquality <- transform(airquality, Month = factor(Month))
> m <- lm(Ozone ~ Month * Wind, data = airquality)
> coefficients(m)
```

(Intercept)	Month6	Month7	Month8	Month9	Wind
50.748	-41.793	68.296	82.211	23.439	-2.368
Month6:Wind	Month7:Wind	Month8:Wind	Month9:Wind		
4.051	-4.663	-6.154	-1.874		

When a parameter vector β of (systematic) effects have been estimated, interest is often in a particular estimable function, i.e. linear combination $\lambda^\top \beta$ and/or testing the hypothesis $H_0 : \lambda^\top \beta = \beta_0$ where λ is a specific vector defined by the user.

Suppose for example we want to calculate the expected difference in ozone between consecutive months at wind speed 10 mph (which is about the average wind speed over the whole period).

The `esticon` function provides a way of doing so. We can specify several λ vectors at the same time. For example

```
> Lambda
```

	[,1]	[,2]	[,3]	[,4]	[,5]	[,6]	[,7]	[,8]	[,9]	[,10]
[1,]	0	-1	0	0	0	0	-10	0	0	0
[2,]	0	1	-1	0	0	0	10	-10	0	0
[3,]	0	0	1	-1	0	0	0	10	-10	0
[4,]	0	0	0	1	-1	0	0	0	10	-10

```
> esticon(m, Lambda)
```

```
Confidence interval ( WALD ) level = 0.95
```

	beta0	Estimate	Std.Error	t.value	DF	Pr(> t)	Lower.CI	Upper.CI
1	0	1.2871	10.238	0.1257	106	0.90019	-19.010	21.585
2	0	-22.9503	10.310	-2.2259	106	0.02814	-43.392	-2.509
3	0	0.9954	7.094	0.1403	106	0.88867	-13.069	15.060
4	0	15.9651	6.560	2.4337	106	0.01662	2.959	28.971

In other cases, interest is in testing a hypothesis of a contrast $H_0 : \Lambda\beta = \beta_0$ where Λ is a matrix. For example a test of no interaction between `Month` and `Wind` can be made by testing jointly that the last four parameters in `m` are zero (observe that the test is a Wald test):


```

> Lambda

      [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10]
[1,]    0    0    0    0    0    0    1    0    0    0
[2,]    0    0    0    0    0    0    0    1    0    0
[3,]    0    0    0    0    0    0    0    0    1    0
[4,]    0    0    0    0    0    0    0    0    0    1

> esticon(m, Lambda, joint.test = T)

      X2.stat DF Pr(>|X^2|)
1      22.11  4  0.0001906

```

For a linear normal model, one would typically prefer to do a likelihood ratio test instead. However, for generalized estimating equations of glm-type (as dealt with in the packages `geepack` and `gee`) there is no likelihood. In this case `esticon` function provides an operational alternative.

Observe that another function for calculating contrasts as above is the `contrast` function in the `Design` package but it applies to a narrower range of models than `esticon` does.

10 Final remarks

The `esticon` functions and other smaller functions are likely to be removed from the `doBy` package in the future. Credit is due to Dennis Chabot, Gabor Grothendieck, Paul Murrell and Erik Jørgensen for reporting various bugs and making various suggestions to the functionality in the `doBy` package.