Package 'lmerTest'

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Type Package

Title Tests for random and fixed effects for linear mixed effect models (lmer objects of lme4 package).

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Imports numDeriv, MASS, Hmisc, gplots, pbkrtest

Description The package provides different kinds of tests on lmer objects (of lme4 package). The tests comprise type 3 and type 1 F tests for fixed effects, LRT tests for random effects, calculation of population means for fixed factors with confidence intervals and corresponding plots. Package also provides backward elimination of non-significant effects

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`lmerTest-package` *The package performs different kinds of tests on lmer objects, such as* F *tests of type 3/type 1 hypotheses for the fixed part, likelihood ratio tests for the random part, least squares means (population means) and differences of least squares means for the factors of the fixed part with corresponding plots. The package also provides with a function step, that preforms backward elimination of non-significant effects, starting from the random effects, and then fixed ones.*

Description

The package provides anova function, that gives data frame similar to what gives **lme4** package but with p-values calculated from F statistics of type 3/type 1 hypotheses. There are two options for denominator degrees of freedom of F statistics: "Satterthwaite" and "Kenward-Roger". The calculation of anova with Kenward-Roger's approximation is based on function from **pbkrtest** package, the calculation of Satterthwaite's approximation is based on SAS proc mixed theory (see reference).The type 3 hypothesis (marginal) is calculated according to SAS theory (SAS Institute Inc., 1978). The package also provides `summary` function, which gives the same as **lme4** package summary function but with p-values and degrees of freedom added for the t-test (based on Satterthwaite approximation for denominator degrees of freedom). The tests on random effects are performed using likelihood ratio tests.

Details

Package:	lmerTest
Type:	Package
Version:	1.0
Date:	2012-01-10
License:	GPL

The calculation of statistics for the fixed part was developed according to SAS Proc Mixed Theory (see reference).

Author(s)

Alexandra Kuznetsova <alku@dtu.dk>, Per Bruun Brockhoff, Rune Haubo Bojesen Christensen

References

SAS Technical Report R-101 1978 Tests of Hypotheses in Fixed-Effects Linear Models *Copyright (C)* (SAS Institute Inc., Cary, NC, USA)

Goodnight, J.H. 1976 General Linear Models Procedure (S.A.S. Institute, Inc.)

Schaalje G.B., McBride J.B., Fellingham G.W. 2002 Adequacy of approximations to distributions of test Statistics in complex mixed linear models

Examples

```
#import lmerTest package
library(lmerTest)

# an object of class merModLmerTest
m <- lmer(Informed.liking ~ Gender+Information+Product +(1|Consumer), data=ham)

# gives summary of lmer object. The same as of class merMod but with
# additional p-values calculated based on Satterthwate's approximations
summary(m)

# anova table the same as of class merMod but with additional F statistics and
#  and denominator degrees of freedom and
# p-values calculated based on Satterthwaite's approximations
anova(m)

# anova table the same as of class merMod but with additional F statistics and
# denominator degrees of freedom and
# p-values calculated based on Kenward-Roger's approximations
anova(m, ddf="Kenward-Roger")

# anova table of class merMod
anova(m, ddf="lme4")

# backward elimination of non-significant effects of model m
st <- step(m)

plot(st)
```

---

anova-methods *Methods for function* anova *in package* **lmerTest**

Description

Methods for Function anova in Package **lmerTest**

Usage

```
## S4 method for signature 'merModLmerTest'
anova(object, ... , ddf="Satterthwaite", type=3, method.grad="simple")
```

Arguments

object	object of class "merModLmerTest"
...	object of class "merModLmerTest". Then the model comparison statistisc will be calculated
ddf	By default the Satterthwaite's approximation to degrees of freedom is calculated. If ddf="Kenward-Roger", then the Kenward-Roger's approximation is calculated using KRmodcomp function from **pbkrtest** package. If ddf="lme4" then the anova table that comes from **lme4** package is returned.
type	type of hypothesis to be tested. Could be type=3 or type=1 (The definition comes from SAS theory)
method.grad	"simple" is the default one and the fastest one. "Richardson" gives more accurate results. This argument only applies to ddf="Satterthwaite"

References

SAS Technical Report R-101 1978 Tests of Hypotheses in Fixed-Effects Linear Models *Copyright (C)* (SAS Institute Inc., Cary, NC, USA)

Goodnight, J.H. 1976 General Linear Models Procedure (S.A.S. Institute, Inc.)

Schaalje G.B., McBride J.B., Fellingham G.W. 2002 Adequacy of approximations to distributions of test Statistics in complex mixed linear models

Examples

```
#import lmerTest package
library(lmerTest)

m.ham <- lmer(Informed.liking ~ Product*Information*Gender
+ (1|Consumer), data=ham)

# type 3 anova table with  denominator degrees of freedom
# calculated based on Satterthwaite's approximation
anova(m.ham)

# type 1 anova table with denominator degrees of freedom
# calculated based on Satterthwaite's approximation
anova(m.ham, type=1)

# type3 anova table with additional F statistics and denominator degrees of freedom
# calculated based on Kenward-Roger's approximation
anova(m.ham, ddf="Kenward-Roger")

# anova table, that is returned by lme4 package
anova(m.ham, ddf="lme4")
```

carrots *Consumer preference mapping of carrots*

Description

In a consumer study 103 consumers scored their preference of 12 danish carrot types on a scale from 1 to 7. Moreover the consumers scored the degree of sweetness, bitterness and crispiness in the products. The carrots were harvested in autumn 1996 and tested in march 1997. In addition to the consumer survey, the carrot products were evaluated by a trained panel of tasters, the sensory panel, with respect to a number of sensory (taste, odour and texture) properties. Since usually a high number of (correlated) properties(variables) are used, in this case 14, it is a common procedure to use a few, often 2, combined variables that contain as much of the information in the sensory variables as possible. This is achieved by extracting the first two principal components in a principal components analysis(PCA) on the product-by-property panel average data matrix. In this data set the variables for the first two principal components are named (`sens1` and `sens2`).

Usage

```
carrots
```

Format

`Consumer` factor with 103 levels: numbering identifying consumers

`Frequency` factor with 5 levels; "How often do you eat carrots?" 1: once a week or more, 2: once every two weeks, 3: once every three weeks, 4: at least once month, 5: less than once a month

`Gender` factor with 2 levels. 1: male, 2:female

`Age` factor with 4 levels. 1: less than 25 years, 2: 26-40 years, 3: 41-60 years, 4 more than 61 years

`Homesize` factor with two levels. Number of persons in the household. 1: 1 or 2 persons, 2: 3 or more persons

`Work` factor with 7 levels. different types of employment. 1: unskilled worker(no education), 2: skilled worker(with education), 3: office worker, 4: housewife (or man), 5: independent businessman/ self-employment, 6: student, 7: retired

`Income` factor with 4 levels. 1: <150000, 2: 150000-300000, 3: 300000-500000, 4: >500000

Source

Per Bruun Brockhoff, The Royal Veterinary and Agricultural University, Denmark.

Examples

```
#import lme4 package and lmerTest package
library(lmerTest)

m.carrots <- lmer(Preference ~ sens2 + Homesize
+(1+sens2|Consumer), data=carrots)
```

```
# only elimination of the random part is required.
#approximation of ddf is Kenward-Roger
step(m.carrots, ddf="Kenward-Roger")
```

`difflsmeans` *Calculates Differences of Least Squares Means and Confidence Intervals for the factors of a fixed part of mixed effects model of lmer object.*

Description

Produces a data frame which resembles to what SAS software gives in proc mixed statement. The approximation for degrees of freedom is Satterthwaite's.

Usage

```
difflsmeans(model, test.effs=NULL, method.grad="simple",...)
```

Arguments

`model`	linear mixed effects model (lmer object).
`test.effs`	charachter vector specyfying the names of terms to be tested. If NULL all the terms are tested.
`method.grad`	approximation method for the grad function, which is used in calculation of denominator degrees of freedom. Could be "simple" or "Richardson". "simple" is the default and the faster one.
`...`	other potential arguments.

Value

Produces Differences of Least Squares Means (population means) table with p-values and Confidence intervals.

Author(s)

Alexandra Kuznetsova, Per Bruun Brockhoff, Rune Haubo Bojesen Christensen

See Also

`lsmeans`, `step`, `rand`

Examples

```
#import lme4 package and lmerTest package
library(lmerTest)

#specify lmer model
m1 <- lmer(Informed.liking ~ Gender*Information +(1|Consumer), data=ham)

#calculate least squares means for interaction Gender:Information
difflsmeans(m1, test.effs="Gender:Information")

#import TVbo data from lmerTest package
data(TVbo)

m <- lmer(Coloursaturation ~ TVset*Picture + (1|Assessor), data=TVbo)
plot(difflsmeans(m, test.effs="TVset"))
```

---

ham *Conjoint study of dry cured ham*

Description

One of the purposes of the study was to investigate the effect of information given to the consumers measured in hedonic liking for the hams. Two of the hams were Spanish and two were Norwegian, each origin representing different salt levels and different aging time. The information about origin was given in such way that both true and false information was given. essentially a 4*2 design with 4 samples and 2 information levels. A total of 81 Consumers participated in the study.

Usage

```
ham
```

Format

`Consumer` factor with 81 levels: numbering identifying consumers

`Product` factor with four levels

`Informed.liking` numeric: hedonic liking for the products

`Information` factor with two levels

`Gender` factor with two levels (gender)

`Age` numeric: age of Consumer

References

"Alternative methods for combining design variables and consumer preference with information about attitudes and demographics in conjoint analysis" . T. Naes, V.Lengard, S. Bolling Johansen, M. Hersleth

Examples

```
#import lmerTest package
library(lmerTest)

m <- lmer(Informed.liking ~ Product*Information*Gender
+ (1|Product:Consumer) , data=ham)

#anova table with p-values with Satterthwaite's approximation for denominator
#degrees of freedom
anova(m)

#analysis of random and fixed parts and post hoc
#analysis of Product and Information effects
step(m, reduce.random=FALSE, reduce.fixed=FALSE,
test.effs=c("Product", "Information"))
```

`lmer` *Fit Linear Mixed-Effects Models*

Description

Fit a linear mixed model

Details

This `lmer` function is an overloaded function of `lmer` (`merMod` class from **lme4** package).

Value

An object of class "`merModLmerTest`"

See Also

`merModLmerTest` class

Examples

```
library(lmerTest)

## linear mixed models
fm1 <- lmer(Reaction ~ Days + (Days|Subject), sleepstudy)
fm2 <- lmer(Reaction ~ Days + (1|Subject) + (0+Days|Subject), sleepstudy)

# anova table the same as of class merMod but with additional F statistics and
# p-values calculated based on Satterthwaite's approximations
anova(fm1)
```

```
# anova table the same as of class merMod but with additional F statistics and
# p-values calculated based on Kenward-Roger's approximations
anova(fm1, ddf="Kenward-Roger")

# anova table the same as of class merMod
anova(fm1, ddf="lme4")

# gives summary of merModLmerTest class. The same as of class merMod but with
# additional p-values calculated based on Satterthwate's approximations
summary(fm1)

## multiple comparisons statistics. The one from lme4 package
anova(fm1, fm2)
```

`lsmeans` *Calculates Least Squares Means and Confidence Intervals for the factors of a fixed part of mixed effects model of lmer object.*

Description

Produces a data frame which resembles to what SAS software gives in proc mixed statement. The approximation of degrees of freedom is Satterthwate's.

Usage

```
lsmeans(model, test.effs=NULL, method.grad="simple",...)
```

Arguments

`model`	linear mixed effects model (lmer object).
`test.effs`	charachter vector specyfying the names of terms to be tested. If NULL all the terms are tested.
`method.grad`	approximation method for the grad function, which is used in calculation of denominator degrees of freedom. Could be "simple" or "Richardson". "simple" is the default one (and the faster one).
`...`	other potential arguments.

Value

Produces Least Squares Means (population means) table with p-values and Confidence intervals.

Note

For construction of the contrast matrix popMatrix function from **doBy** package was used.

Author(s)

Alexandra Kuznetsova, Per Bruun Brockhoff, Rune Haubo Bojesen Christensen

References

doBy package, **gplots** package

See Also

step, rand, difflsmeans

Examples

```
#import lme4 package and lmerTest package
library(lmerTest)

#specify lmer model
m1 <- lmer(Informed.liking ~ Gender*Information +(1|Consumer), data=ham)

#calculate least squares means for interaction Gender:Information
lsmeans(m1, test.effs="Gender:Information")

#import TVbo data from lmerTest package
data(TVbo)

m <- lmer(Coloursaturation ~ TVset*Picture + (1|Assessor), data=TVbo)
plot(lsmeans(m))
lsmeans(m, test.effs="TVset")
```

---

merModLmerTest-class *Mixed Model Representations*

Description

The merModLmerTest *contains* merMod class of **lme4** package and overloads anova and summary functions.

Objects from the Class

Objects can be created via the lmer functions.

See Also

lmer()

Examples

```
(m <- lmer(Reaction ~ Days + (1|Subject) + (0+Days|Subject),
            data = sleepstudy))

# type 3 anova table with  denominator degrees of freedom
# calculated based on Satterthwaite's approximation
anova(m)

# type 1 anova table with denominator degrees of freedom
# calculated based on Satterthwaite's approximation
anova(m, type=1)

# type3 anova table with additional F statistics and denominator degrees of freedom
# calculated based on Kenward-Roger's approximation
anova(m, ddf="Kenward-Roger")

# anova table, that is returned by lme4 package
anova(m, ddf="lme4")

# summary of merModLmerTest object. Returns the same as merMod object but with an
#additional column of p values for the t test.
summary(m)
```

`rand` *Performs likelihood ratio test on random effects of linear mixed effects model.*

Description

Returns a data frame with values of Chi square statistics and corresponding p-values of likelihood ratio tests.

Usage

```
rand(model, ...)
```

Arguments

`model`	linear mixed effects model (lmer object).
`...`	other potential arguments.

Details

The columns of the data are:

Chisq: The value of the chi square statistics

Chi Df: The degrees of freedom for the test

p.value: The p-value of the likelihood ratio test for the effect

Value

Produces a data frame with tests for the random terms being non-significant.

Author(s)

Alexandra Kuznetsova, Per Bruun Brockhoff, Rune Haubo Bojesen Christensen

See Also

step, lsmeans, difflsmeans

Examples

```
#import lme4 package and lmerTest package
library(lmerTest)

#lmer model with correlation between intercept and slopes
#in the random part
m <- lmer(Preference ~ sens2+Homesize+(1+sens2|Consumer), data=carrots)

# table with  p-values for the random effects
rand(m)
```

`step` *Performs backward elimination of non-significant effects of linear mixed effects model:*

Description

performs automatic backward elimination of all effects of linear mixed effect model. First backward elimination of the random part is performed following by backward elimination of the fixed part. Finally LSMEANS (population means) and differences of LSMEANS for the fixed part of the model are calculated and the final model is provided. The p-values for the fixed effects are calculated from F test based on Sattethwaite's or Kenward-Roger approximation), p-values for the random effects are based on likelihood ratio test. All analysis may be performed on `lmer` object of **lme4** package.

Usage

```
step(model, ddf="Satterthwaite", type=3, alpha.random = 0.1, alpha.fixed = 0.05,
reduce.fixed = TRUE, reduce.random = TRUE, lsmeans.calc=TRUE,
difflsmeans.calc=TRUE, test.effs=NULL, method.grad="simple",  ...)
```

Arguments

model	linear mixed effects model (lmer object).
ddf	approximation for denominator degrees of freedom. By default Satterthwaite's approximation. ddf="Kenward-Roger"" calculates Kenward-Roger approximation
type	type of hypothesis to be tested (SAS notation). Either type=1 or type=3.
alpha.random	significance level for elimination of the random part (for LRT test)
alpha.fixed	significance level for elimination of the fixed part (for F test and t-test for least squares means)
reduce.fixed	logical for whether the reduction of the fixed part is required
reduce.random	logical for whether the reduction of the random part is required
lsmeans.calc	logical for whether the calculation of LSMEANS(population means) is required
difflsmeans.calc	logical for whether the calculation of differences of LSMEANS is required
test.effs	charachter vector specifying the names of terms to be tested in LSMEANS. If NULL all the terms are tested. If lsmeans.calc==FALSE then LSMEANS are not calculated.
method.grad	approximation method for the grad function, which is used in calculation of denominator degrees of freedom. Could be "simple" or "Richardson". "simple" is the default one.
...	other potential arguments.

Details

Elimination of all effects is done one at a time. Elimination of the fixed part is done by the principle of marginality that is: the highest order interactions are tested first: if they are significant, the lower order effects are not tested for significance.

Value

rand.table	data frame with value of Chi square statistics, p-values for the likelihood ratio test for random effects
anova.table	data frame with tests for whether the model fixed terms are significant (Analysis of Variance)
lsmeans.table	Least Squares Means data frame with p-values and Confidence intervals
diffs.lsmeans.table	Differences of Least Squares Means data frame with p-values and Confidence intervals
model	Final model - object of merLmerTest(contains mer class) or gls (after all the required reduction has been performed)

Note

For the random coefficient models: in the random part if correlation is present between slope and intercept, then the simplified model will contain just an intercept. That is if the random part of the initial model is `(1+c|f)`, where `c` is a covariate, then this model is compared to `(1|f)` by using LRT. If there are multiple slopes, then the the slope with the highest p-value (and higher then alpha level) is eliminated. That is if the random part of the initial model has the following form `(1+c1+c2|f)`, where `c1` and `c2` are covariates, then two simplified models are constracted and compared to the initial one: the first one has `(1+c1|f)` in the random part and the second one has: `(1+c2|f)`. The simplification of the random part does not consider the cases where `c` is a factor (is left for the future implementation).

Author(s)

Alexandra Kuznetsova, Per Bruun Brockhoff, Rune Haubo Bojesen Christensen

See Also

`rand`, `lsmeans`, `difflsmeans`

Examples

```
#import lme4 package and lmerTest package
library(lmerTest)

## Not run:
m <- lmer(Informed.liking ~ Product*Information*Gender+
(1|Consumer) + (1|Product:Consumer), data=ham)


#elimination of non-significant effects
s <- step(m)

#plot of post-hoc analysis of the final model
plot(s)

## End(Not run)
```

`summary-methods` *Methods for Function* `summary` *in Package* **lmerTest**

Description

Methods for function summary in package **lmerTest**

Methods

signature(object = "merModLmerTest", ...) summary of the results of linear mixed effects model fitting of object. Returns a similar to summary function of "merMod" class but with additional columns with the names "df", "t value" and "Pr(>t)" representing degrees of freedom, t-statistics and p-values respectively calculated based on Satterthwaite's approximation. summary

Examples

```
(fm1 <- lmer(Reaction ~ Days + (Days | Subject), sleepstudy))

# will give you an additional column with p values for the t test
summary(fm1)

#will give the summary of lme4 package
summary(fm1, ddf="lme4")
```

TVbo *TV dataset*

Description

The TVbo dataset comes from Bang and Olufsen company. The main purpose was to test products, specified by two attributes Picture and TVset. 15 different response variables (characteristics of the product) were assessed by trained panel list.

Usage

```
TVbo
```

Format

Assessor factor: numbering identifying assessors

TVset factor: attribute of the product

Picture factor: attribute of the product

15 Characteristics of the product numeric variables: Coloursaturation, Colourbalance, Noise, Depth, Sharpness, Lightlevel, Contrast, Sharpnessofmovement, Flickeringstationary, Flickeringmovement, Distortion, Dimglasseffect, Cutting, Flossyedges, Elasticeffect

Source

Bang and Olufsen company

Examples

```
#import lme4 package and lmerTest package
library(lmerTest)



## Not run:
m <- lmer(Coloursaturation ~ TVset*Picture+
(1|Assessor)+(1|Assessor:TVset), data=TVbo)

step(m, test.effs="TVset", reduce.fixed=FALSE, reduce.random=TRUE)

## End(Not run)
```

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