

# Package ‘lme4’

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**Version** 1.1-12

**Title** Linear Mixed-Effects Models using 'Eigen' and S4

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**Description** Fit linear and generalized linear mixed-effects models.

The models and their components are represented using S4 classes and methods. The core computational algorithms are implemented using the 'Eigen' C++ library for numerical linear algebra and 'RcppEigen' ``glue".

**Depends** R (>= 3.0.2), Matrix (>= 1.1.1), methods, stats

**LinkingTo** Rcpp (>= 0.10.5), RcppEigen

**Imports** graphics, grid, splines, utils, parallel, MASS, lattice, nlme (>= 3.1-123), minqa (>= 1.1.15), nloptr (>= 1.0.4)

**Suggests** knitr, boot, PKPDmodels, MEMSS, testthat (>= 0.8.1), ggplot2, mlmRev, optimx (>= 2013.8.6), gamm4, pbkrtest, HSAUR2, numDeriv

**VignetteBuilder** knitr

**LazyData** yes

**License** GPL (>= 2)

**URL** <https://github.com/lme4/lme4/> <http://lme4.r-forge.r-project.org/>

**BugReports** <https://github.com/lme4/lme4/issues>

**NeedsCompilation** yes

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**Description**

lme4 provides functions for fitting and analyzing mixed models: linear ([lmer](#)), generalized linear ([glmer](#)) and nonlinear ([nlmer](#).)

### Differences between nlme and lme4

**lme4** covers approximately the same ground as the earlier **nlme** package. The most important differences are:

- **lme4** uses modern, efficient linear algebra methods as implemented in the Eigen package, and uses reference classes to avoid undue copying of large objects; it is therefore likely to be faster and more memory-efficient than **nlme**.
- **lme4** includes generalized linear mixed model (GLMM) capabilities, via the `glmer` function.
- **lme4** does *not* currently implement **nlme**'s features for modeling heteroscedasticity and correlation of residuals.
- **lme4** does not currently offer the same flexibility as **nlme** for composing complex variance-covariance structures, but it does implement crossed random effects in a way that is both easier for the user and much faster.
- **lme4** offers built-in facilities for likelihood profiling and parametric bootstrapping.
- **lme4** is designed to be more modular than **nlme**, making it easier for downstream package developers and end-users to re-use its components for extensions of the basic mixed model framework. It also allows more flexibility for specifying different functions for optimizing over the random-effects variance-covariance parameters.
- **lme4** is not (yet) as well-documented as **nlme**.

### Differences between current (1.0.+) and previous versions of lme4

- `[gn]lmer` now produces objects of class `merMod` rather than class `mer` as before
- the new version uses a combination of S3 and reference classes (see [ReferenceClasses](#), [merPredD-class](#), and [lmResp-class](#)) as well as S4 classes; partly for this reason it is more interoperable with **nlme**
- The internal structure of `[gn]lmer` is now more modular, allowing finer control of the different steps of argument checking; construction of design matrices and data structures; parameter estimation; and construction of the final `merMod` object (see [modular](#))
- profiling and parametric bootstrapping are new in the current version
- the new version of **lme4** does *not* provide an `mcmc` (post-hoc MCMC sampling) method, because this was deemed to be unreliable. Alternatives for computing p-values include parametric bootstrapping (`bootMer`) or methods implemented in the **pbkrtest** package and leveraged by the **lmerTest** package and the `Anova` function in the **car** package (see [pvalues](#) for more details).

### Caveats and trouble-shooting

- Some users who have previously installed versions of the `RcppEigen` and `minqa` packages may encounter segmentation faults (!!); the solution is to make sure to re-install these packages before installing **lme4**. (Because the problem is not with the explicit *version* of the packages, but with running packages that were built with different versions of **Rcpp** in conjunction with each other, simply making sure you have the latest version, or using `update.packages`, will not necessarily solve the problem; you must actually re-install the packages. The problem is most likely with `minqa`.)

---

 Arabidopsis

*Arabidopsis clipping/fertilization data*


---

**Description**

Data on genetic variation in responses to fertilization and simulated herbivory in *Arabidopsis*

**Usage**

```
data("Arabidopsis")
```

**Format**

A data frame with 625 observations on the following 8 variables.

reg region: a factor with 3 levels NL (Netherlands), SP (Spain), SW (Sweden)

popu population: a factor with the form n.R representing a population in region R

gen genotype: a factor with 24 (numeric-valued) levels

rack a nuisance factor with 2 levels, one for each of two greenhouse racks

nutrient fertilization treatment/nutrient level (1, minimal nutrients or 8, added nutrients)

amd simulated herbivory or "clipping" (apical meristem damage): unclipped (baseline) or clipped

status a nuisance factor for germination method (Normal, Petri.Plate, or Transplant)

total.fruits total fruit set per plant (integer)

**Source**

From Josh Banta

**References**

Joshua A. Banta, Martin H. H Stevens, and Massimo Pigliucci (2010) A comprehensive test of the 'limiting resources' framework applied to plant tolerance to apical meristem damage. *Oikos* **119**(2), 359–369; <http://dx.doi.org/10.1111/j.1600-0706.2009.17726.x>

**Examples**

```
data(Arabidopsis)
summary(Arabidopsis[, "total.fruits"])
table(gsub("[0-9].", "", levels(Arabidopsis[, "popu"])))
library(lattice)
stripplot(log(total.fruits+1) ~ amd|nutrient, data = Arabidopsis,
          groups = gen,
          strip=strip.custom(strip.names=c(TRUE, TRUE)),
          type=c('p', 'a'), ## points and panel-average value --
          ## see ?panel.xyplot
          scales=list(x=list(rot=90)),
          main="Panel: nutrient, Color: genotype")
```

bootMer

*Model-based (Semi-)Parametric Bootstrap for Mixed Models***Description**

Perform model-based (Semi-)parametric bootstrap for mixed models.

**Usage**

```
bootMer(x, FUN, nsim = 1, seed = NULL, use.u = FALSE, re.form=NA,
        type = c("parametric", "semiparametric"),
        verbose = FALSE, .progress = "none", PBargs = list(),
        parallel = c("no", "multicore", "snow"),
        ncpus = getOption("boot.ncpus", 1L), cl = NULL)
```

**Arguments**

x	a fitted merMod object: see <a href="#">lmer</a> , <a href="#">glmer</a> , etc.
FUN	a function taking a fitted merMod object as input and returning the <i>statistic</i> of interest, which must be a (possibly named) numeric vector.
nsim	number of simulations, positive integer; the bootstrap $B$ (or $R$ ).
seed	optional argument to <a href="#">set.seed</a> .
use.u	logical, indicating whether the spherical random effects should be simulated / bootstrapped as well. If TRUE, they are not changed, and all inference is conditional on these values. If FALSE, new normal deviates are drawn (see Details).
re.form	formula, NA (equivalent to use.u=FALSE), or NULL (equivalent to use.u=TRUE): alternative to use.u for specifying which random effects to incorporate. See <a href="#">simulate.merMod</a> for details.
type	character string specifying the type of bootstrap, "parametric" or "semiparametric"; partial matching is allowed.
verbose	logical indicating if progress should print output
.progress	character string - type of progress bar to display. Default is "none"; the function will look for a relevant *ProgressBar function, so "txt" will work in general; "tk" is available if the <b>tcltk</b> package is loaded; or "win" on Windows systems. Progress bars are disabled (with a message) for parallel operation.
PBargs	a list of additional arguments to the progress bar function (the package authors like <code>list(style=3)</code> ).
parallel	The type of parallel operation to be used (if any). If missing, the default is taken from the option "boot.parallel" (and if that is not set, "no").
ncpus	integer: number of processes to be used in parallel operation: typically one would choose this to be the number of available CPUs.
cl	An optional <b>parallel</b> or <b>snow</b> cluster for use if parallel = "snow". If not supplied, a cluster on the local machine is created for the duration of the boot call.

## Details

The semi-parametric variant is only partially implemented, and we only provide a method for `lmer` and `glmer` results.

The working name for `bootMer()` was “`simulestimate()`”, as it is an extension of `simulate` (see `simulate.merMod`), but we want to emphasize its potential for valid inference.

- If `use.u` is `FALSE` and `type` is “`parametric`”, each simulation generates new values of both the “*spherical*” random effects  $u$  and the i.i.d. errors  $\epsilon$ , using `rnorm()` with parameters corresponding to the fitted model  $x$ .
- If `use.u` is `TRUE` and `type`==“`parametric`”, only the i.i.d. errors (or, for GLMMs, response values drawn from the appropriate distributions) are resampled, with the values of  $u$  staying fixed at their estimated values.
- If `use.u` is `TRUE` and `type`==“`semiparametric`”, the i.i.d. errors are sampled from the distribution of (response) residuals. (For GLMMs, the resulting sample will no longer have the same properties as the original sample, and the method may not make sense; a warning is generated.) The semiparametric bootstrap is currently an experimental feature, and therefore may not be stable.
- The case where `use.u` is `FALSE` and `type`==“`semiparametric`” is not implemented; Morris (2002) suggests that resampling from the estimated values of  $u$  is not good practice.

## Value

an object of S3 class “`boot`”, compatible with `boot` package’s `boot()` result.

## References

Davison, A.C. and Hinkley, D.V. (1997) *Bootstrap Methods and Their Application*. Cambridge University Press.

Morris, J. S. (2002). The BLUPs Are Not ‘best’ When It Comes to Bootstrapping. *Statistics & Probability Letters* **56**(4): 425–430. doi:10.1016/S0167-7152(02)00041-X.

## See Also

- `confint.merMod`, for a more specific approach to bootstrap confidence intervals on parameters.
- `refit()`, or `PBmodcomp()` from the `pbrtest` package, for parametric bootstrap comparison of models.
- `boot()`, and then `boot.ci`, from the `boot` package.
- `profile-methods`, for likelihood-based inference, including confidence intervals.
- `pvalues`, for more general approaches to inference and p-value computation in mixed models.

## Examples

```
fm01ML <- lmer(Yield ~ 1|Batch, Dyestuff, REML = FALSE)
## see ?"profile-methods"
mySumm <- function(.) { s <- sigma(.)
  c(beta = getME(., "beta"), sigma = s, sig01 = unname(s * getME(., "theta"))) }
```

```

(t0 <- mySumm(fm01ML)) # just three parameters
## alternatively:
mySumm2 <- function(.) {
  c(beta=fixef(.),sigma=sigma(.), sig01=sqrt(unlist(VarCorr(.))))
}

set.seed(101)
## 3.8s (on a 5600 MIPS 64bit fast(year 2009) desktop "AMD Phenom(tm) II X4 925"):
system.time( boo01 <- bootMer(fm01ML, mySumm, nsim = 100) )

## to "look" at it
require("boot") ## a recommended package, i.e. *must* be there
boo01
## note large estimated bias for sig01
## (~30% low, decreases _slightly_ for nsim = 1000)

## extract the bootstrapped values as a data frame ...
head(as.data.frame(boo01))

## ----- Bootstrap-based confidence intervals -----

## warnings about "Some ... intervals may be unstable" go away
## for larger bootstrap samples, e.g. nsim=500

## intercept
(bCI.1 <- boot.ci(boo01, index=1, type=c("norm", "basic", "perc")))# beta

## Residual standard deviation - original scale:
(bCI.2 <- boot.ci(boo01, index=2, type=c("norm", "basic", "perc"))
## Residual SD - transform to log scale:
(bCI.2L <- boot.ci(boo01, index=2, type=c("norm", "basic", "perc"),
  h = log, hdot = function(.) 1/., hinv = exp))

## Among-batch variance:
(bCI.3 <- boot.ci(boo01, index=3, type=c("norm", "basic", "perc"))) # sig01

## Extract all CIs (somewhat awkward)
bCI.tab <- function(b,ind=length(b$t0), type="perc", conf=0.95) {
  btab0 <- t(sapply(as.list(seq(ind)),
    function(i)
      boot.ci(b,index=i,conf=conf, type=type)$percent))
  btab <- btab0[,4:5]
  rownames(btab) <- names(b$t0)
  a <- (1 - conf)/2
  a <- c(a, 1 - a)
  pct <- stats::format.perc(a, 3)
  colnames(btab) <- pct
  return(btab)
}
bCI.tab(boo01)

## Graphical examination:
plot(boo01,index=3)

```



```
## Check stored values from a longer (1000-replicate) run:
load(system.file("testdata", "boo01L.RData", package="lme4"))
plot(boo01L, index=3)
mean(boo01L$t[, "sig01"]==0) ## note point mass at zero!
```

---

cake

*Breakage Angle of Chocolate Cakes*


---

### Description

Data on the breakage angle of chocolate cakes made with three different recipes and baked at six different temperatures. This is a split-plot design with the recipes being whole-units and the different temperatures being applied to sub-units (within replicates). The experimental notes suggest that the replicate numbering represents temporal ordering.

### Format

A data frame with 270 observations on the following 5 variables.

replicate a factor with levels 1 to 15

recipe a factor with levels A, B and C

temperature an ordered factor with levels 175 < 185 < 195 < 205 < 215 < 225

angle a numeric vector giving the angle at which the cake broke.

temp numeric value of the baking temperature (degrees F).

### Details

The replicate factor is nested within the recipe factor, and temperature is nested within replicate.

### Source

Original data were presented in Cook (1938), and reported in Cochran and Cox (1957, p. 300). Also cited in Lee, Nelder and Pawitan (2006).

### References

Cook, F. E. (1938) *Chocolate cake, I. Optimum baking temperature*. Master's Thesis, Iowa State College.

Cochran, W. G., and Cox, G. M. (1957) *Experimental designs*, 2nd Ed. New York, John Wiley & Sons.

Lee, Y., Nelder, J. A., and Pawitan, Y. (2006) *Generalized linear models with random effects. Unified analysis via H-likelihood*. Boca Raton, Chapman and Hall/CRC.

**Examples**

```

str(cake)
## 'temp' is continuous, 'temperature' an ordered factor with 6 levels

(fm1 <- lmer(angle ~ recipe * temperature + (1|recipe:replicate), cake, REML= FALSE))
(fm2 <- lmer(angle ~ recipe + temperature + (1|recipe:replicate), cake, REML= FALSE))
(fm3 <- lmer(angle ~ recipe + temp          + (1|recipe:replicate), cake, REML= FALSE))

## and now "choose" :
anova(fm3, fm2, fm1)

```

---

cbpp

*Contagious bovine pleuropneumonia*


---

**Description**

Contagious bovine pleuropneumonia (CBPP) is a major disease of cattle in Africa, caused by a mycoplasma. This dataset describes the serological incidence of CBPP in zebu cattle during a follow-up survey implemented in 15 commercial herds located in the Boji district of Ethiopia. The goal of the survey was to study the within-herd spread of CBPP in newly infected herds. Blood samples were quarterly collected from all animals of these herds to determine their CBPP status. These data were used to compute the serological incidence of CBPP (new cases occurring during a given time period). Some data are missing (lost to follow-up).

**Format**

A data frame with 56 observations on the following 4 variables.

herd A factor identifying the herd (1 to 15).

incidence The number of new serological cases for a given herd and time period.

size A numeric vector describing herd size at the beginning of a given time period.

period A factor with levels 1 to 4.

**Details**

Serological status was determined using a competitive enzyme-linked immuno-sorbent assay (cELISA).

**Source**

Lesnoff, M., Laval, G., Bonnet, P., Abdicho, S., Workalemahu, A., Kifle, D., Peyraud, A., Lancelot, R., Thiaucourt, F. (2004) Within-herd spread of contagious bovine pleuropneumonia in Ethiopian highlands. *Preventive Veterinary Medicine* **64**, 27–40.

## Examples

```
## response as a matrix
(m1 <- glmer(cbind(incidence, size - incidence) ~ period + (1 | herd),
             family = binomial, data = cbpp))
## response as a vector of probabilities and usage of argument "weights"
m1p <- glmer(incidence / size ~ period + (1 | herd), weights = size,
             family = binomial, data = cbpp)
## Confirm that these are equivalent:
stopifnot(all.equal(fixef(m1), fixef(m1p), tolerance = 1e-5),
          all.equal(ranef(m1), ranef(m1p), tolerance = 1e-5))

## GLMM with individual-level variability (accounting for overdispersion)
cbpp$obs <- 1:nrow(cbpp)
(m2 <- glmer(cbind(incidence, size - incidence) ~ period + (1 | herd) + (1|obs),
             family = binomial, data = cbpp))
```

---

confint.merMod

*Compute Confidence Intervals for Parameters of a [ng]lmer Fit*

---

## Description

Compute confidence intervals on the parameters of a `*lmer()` model fit (of class `"merMod"`).

## Usage

```
## S3 method for class 'merMod'
confint(object, parm, level = 0.95,
        method = c("profile", "Wald", "boot"), zeta,
        nsim = 500,
        boot.type = c("perc", "basic", "norm"),
        FUN = NULL, quiet = FALSE,
        oldNames = TRUE, ...)
```

## Arguments

<code>object</code>	a fitted [ng]lmer model
<code>parm</code>	parameters for which intervals are sought. Specified by an integer vector of positions, <a href="#">character</a> vector of parameter names, or (unless doing parametric bootstrapping with a user-specified bootstrap function) <code>"theta_"</code> or <code>"beta_"</code> to specify variance-covariance or fixed effects parameters only: see the which parameter of <a href="#">profile</a> .
<code>level</code>	confidence level < 1, typically above 0.90.
<code>method</code>	a <a href="#">character</a> string determining the method for computing the confidence intervals.
<code>zeta</code>	(for <code>method = "profile"</code> only:) likelihood cutoff (if not specified, as by default, computed from <code>level</code> ).

<code>nsim</code>	number of simulations for parametric bootstrap intervals.
<code>FUN</code>	bootstrap function; if NULL, an internal function that returns the fixed-effect parameters as well as the random-effect parameters on the standard deviation/correlation scale will be used. See <a href="#">bootMer</a> for details.
<code>boot.type</code>	bootstrap confidence interval type, as described in <a href="#">boot.ci</a> . (Methods ‘stud’ and ‘bca’ are unavailable because they require additional components to be calculated.)
<code>quiet</code>	(logical) suppress messages about computationally intensive profiling?
<code>oldNames</code>	(logical) use old-style names for variance-covariance parameters, e.g. “.sig01”, rather than newer (more informative) names such as “sd_(Intercept) Subject”? (See <code>signames</code> argument to <a href="#">profile</a> ).
<code>...</code>	additional parameters to be passed to <a href="#">profile.merMod</a> or <a href="#">bootMer</a> , respectively.

### Details

Depending on the method specified, `confint()` computes confidence intervals by

“profile”: computing a likelihood profile and finding the appropriate cutoffs based on the likelihood ratio test;

“Wald”: approximating the confidence intervals (of fixed-effect parameters only; all variance-covariance parameters CIs will be returned as NA) based on the estimated local curvature of the likelihood surface;

“boot”: performing parametric bootstrapping with confidence intervals computed from the bootstrap distribution according to `boot.type` (see [bootMer](#), [boot.ci](#)).

### Value

a numeric table ([matrix](#) with column and row names) of confidence intervals; the confidence intervals are computed on the standard deviation scale.

### Note

The default method “profile” amounts to

```
confint(profile(object, which=parm), signames=oldNames, ...),
        level, zeta)
```

where the `profile` method [profile.merMod](#) does almost all the computations. Therefore it is typically advisable to store the `profile(.)` result, say in `pp`, and then use `confint(pp, level=*)` e.g., for different levels.

### Examples

```
fm1 <- lmer(Reaction ~ Days + (Days|Subject), sleepstudy)
fm1W <- confint(fm1, method="Wald")# very fast, but ....
fm1W
testLevel <- if (nzchar(s <- Sys.getenv("LME4_TEST_LEVEL"))) as.numeric(s) else 1
```

```

if(interactive() || testLevel >= 3) {
  ## ~20 seconds, MacBook Pro laptop
  system.time(fm1P <- confint(fm1, method="profile", ## default
                             oldNames = FALSE))

  ## ~ 40 seconds
  system.time(fm1B <- confint(fm1,method="boot",
                             .progress="txt", PBargs=list(style=3)))
} else
  load(system.file("testdata", "confint_ex.rda", package="lme4"))
fm1P
fm1B

```

---

convergence

*Assessing Convergence for Fitted Models*


---

## Description

The **lme4** package uses general-purpose nonlinear optimizers (e.g. Nelder-Mead or Powell's BOBYQA method) to estimate the variance-covariance matrices of the random effects. Assessing reliably whether such algorithms have converged is difficult. For example, evaluating the **Karush-Kuhn-Tucker conditions** (convergence criteria which in the simplest case of non-constrained optimization reduce to showing that the gradient is zero and the Hessian is positive definite) is challenging because of the difficulty of evaluating the gradient and Hessian.

We (the lme4 authors and maintainers) are still in the process of finding the best strategies for testing convergence. Some of the relevant issues are

- the gradient and Hessian are the basic ingredients of KKT-style testing, but when they have to be estimated by finite differences (as in the case of lme4; direct computation of derivatives based on analytic expressions may eventually be available for some special classes, but we have not yet implemented them) they may not be sufficiently accurate for reliable convergence testing.
- The Hessian computation in particular represents a difficult tradeoff between computational expense and accuracy. At present the Hessian computations used for convergence checking (and for estimating standard errors of fixed-effect parameters for GLMMs) follow the **ordinal** package in using a naive but computationally cheap centered finite difference computation (with a fixed step size of  $10^{-4}$ ). A more reliable but more expensive approach is to use **Richardson extrapolation**, as implemented in the **numDeriv** package.
- it is important to scale the estimated gradient at the estimate appropriately; two reasonable approaches are
  1. don't scale random-effects (Cholesky) gradients, since these are essentially already unitless (for LMMs they are scaled relative to the residual variance; for GLMMs they are scaled relative to the sampling variance of the conditional distribution); for GLMMs, scale fixed-effect gradients by the standard deviations of the corresponding input variable, or
  2. scale gradients by the inverse Cholesky factor of the Hessian, equivalent to scaling by the estimated Wald standard error of the estimated parameters. The latter approach is

used in the current version of **lme4**; it has the disadvantage that it requires us to estimate the Hessian (although the Hessian is required **for reliable estimation of the fixed-effect standard errors for GLMMs** in any case).

- Exploratory analyses suggest that (1) the naive estimation of the Hessian may fail for large data sets (number of observations greater than approximately  $10^5$ ); (2) the magnitude of the scaled gradient increases with sample size, so that warnings will occur even for apparently well-behaved fits with large data sets.

If you do see convergence warnings, and want to trouble-shoot/double-check the results, the following steps are recommended (examples are given below):

- double-check the model specification and the data for mistakes
- center and scale continuous predictor variables (e.g. with `scale`)
- check for singularity: if any of the diagonal elements of the Cholesky factor are zero or very small, the convergence testing methods may be inappropriate (see examples)
- double-check the Hessian calculation with the more expensive Richardson extrapolation method (see examples)
- restart the fit from the apparent optimum, or from a point perturbed slightly away from the optimum
- try all available optimizers (e.g. several different implementations of BOBYQA and Nelder-Mead, L-BFGS-B from `optim`, `nlminb`, ...) While this will of course be slow for large fits, we consider it the gold standard; if all optimizers converge to values that are practically equivalent, then we would consider the convergence warnings to be false positives.

To quote Douglas Adams, **we apologize for the inconvenience**.

## See Also

[lmerControl](#)

## Examples

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

## 1. center and scale predictors:
ss.CS <- transform(sleepstudy, Days=scale(Days))
fm1.CS <- update(fm1, data=ss.CS)

## 2. check singularity
diag.vals <- getME(fm1,"theta")[getME(fm1,"lower") == 0]
any(diag.vals < 1e-6) # FALSE

## 3. recompute gradient and Hessian with Richardson extrapolation
devfun <- update(fm1, devFunOnly=TRUE)
if (isLMM(fm1)) {
  pars <- getME(fm1,"theta")
} else {
  ## GLMM: requires both random and fixed parameters
  pars <- getME(fm1, c("theta","fixef"))
}
```

```

if (require("numDeriv")) {
  cat("hess:\n"); print(hess <- hessian(devfun, unlist(pars)))
  cat("grad:\n"); print(grad <- grad(devfun, unlist(pars)))
  cat("scaled gradient:\n")
  print(scgrad <- solve(chol(hess), grad))
}
## compare with internal calculations:
fm1@optinfo$derivs

## 4. restart the fit from the original value (or
## a slightly perturbed value):
fm1.restart <- update(fm1, start=pars)

## 5. try all available optimizers

source(system.file("utils", "allFit.R", package="lme4"))
fm1.all <- allFit(fm1)
ss <- summary(fm1.all)
ss$ fixef          ## extract fixed effects
ss$ llik           ## log-likelihoods
ss$ sdcor          ## SDs and correlations
ss$ theta          ## Cholesky factors
ss$ which.OK       ## which fits worked

```

---

devcomp

*Extract the deviance component list*


---

## Description

Return the deviance component list

## Usage

```
devcomp(x)
```

## Arguments

x a fitted model of class `merMod`

## Details

A fitted model of class `merMod` has a `devcomp` slot as described in the value section.

## Value

a list with components

`dims` a named integer vector of various dimensions

`cmp` a named numeric vector of components of the deviance

**Note**

This function is deprecated, use `getME(., "devcomp")`

---

drop1.merMod

*Drop all possible single fixed-effect terms from a mixed effect model*

---

**Description**

Drop allowable single terms from the model: see [drop1](#) for details of how the appropriate scope for dropping terms is determined.

**Usage**

```
## S3 method for class 'merMod'
drop1(object, scope, scale = 0,
      test = c("none", "Chisq", "user"),
      k = 2, trace = FALSE, sumFun, ...)
```

**Arguments**

object	a fitted merMod object.
scope	a formula giving the terms to be considered for adding or dropping.
scale	Currently ignored (included for S3 method compatibility)
test	should the results include a test statistic relative to the original model? The $\chi^2$ test is a likelihood-ratio test, which is approximate due to finite-size effects.
k	the penalty constant in AIC
trace	print tracing information?
sumFun	a summary function to be used when test=="user". It must allow arguments scale and k, but these may be ignored (e.g. specified in dots). The first two arguments must be object, the full model fit, and objectDrop, a reduced model. If objectDrop is missing, sumFun should return a vector of with the appropriate length and names (the actual contents are ignored).
...	other arguments (ignored)

**Details**

drop1 relies on being able to find the appropriate information within the environment of the formula of the original model. If the formula is created in an environment that does not contain the data, or other variables passed to the original model (for example, if a separate function is called to define the formula), then drop1 will fail. A workaround (see example below) is to manually specify an appropriate environment for the formula.

**Value**

An object of class anova summarizing the differences in fit between the models.



**Examples**

```

fm1 <- lmer(Reaction~Days+(Days|Subject),sleepstudy)
## likelihood ratio tests
drop1(fm1,test="Chisq")
## use Kenward-Roger corrected F test, or parametric bootstrap,
## to test the significance of each dropped predictor
if (require(pbkrtest) && packageVersion("pbkrtest")>="0.3.8") {
  KRSumFun <- function(object, objectDrop, ...) {
    krnames <- c("ndf","ddf","Fstat","p.value","F.scaling")
    r <- if (missing(objectDrop)) {
      setNames(rep(NA,length(krnames)),krnames)
    } else {
      krtest <- KRmodcomp(object,objectDrop)
      unlist(krtest$stats[krnames])
    }
    attr(r,"method") <- c("Kenward-Roger via pbkrtest package")
    r
  }
  drop1(fm1,test="user",sumFun=KRSumFun)

  if(lme4:::testLevel() >= 3) { ## takes about 16 sec
    nsim <- 100
    PBSumFun <- function(object, objectDrop, ...) {
    pbnames <- c("stat","p.value")
    r <- if (missing(objectDrop)) {
      setNames(rep(NA,length(pbnames)),pbnames)
    } else {
      pbtest <- PBmodcomp(object,objectDrop,nsim=nsim)
      unlist(pbtest$test[2,pbnames])
    }
    attr(r,"method") <- c("Parametric bootstrap via pbkrtest package")
    r
  }
  system.time(drop1(fm1,test="user",sumFun=PBSumFun))
}
}
## workaround for creating a formula in a separate environment
createFormula <- function(resp, fixed, rand) {
  f <- reformulate(c(fixed,rand),response=resp)
  ## use the parent (createModel) environment, not the
  ## environment of this function (which does not contain 'data')
  environment(f) <- parent.frame()
  f
}
createModel <- function(data) {
  mf.final <- createFormula("Reaction", "Days", "(Days|Subject)")
  lmer(mf.final, data=data)
}
drop1(createModel(data=sleepstudy))

```

---

dummy	<i>Dummy variables (experimental)</i>
-------	---------------------------------------

---

**Description**

Largely a wrapper for `model.matrix` that accepts a factor, `f`, and returns a dummy matrix with `nlevels(f)-1` columns (the first column is dropped by default). Useful whenever one wishes to avoid the behaviour of `model.matrix` of always returning an `nlevels(f)`-column matrix, either by the addition of an intercept column, or by keeping one column for all levels.

**Usage**

```
dummy(f, levelsToKeep)
```

**Arguments**

<code>f</code>	An object coercible to <code>factor</code> .
<code>levelsToKeep</code>	An optional character vector giving the subset of <code>levels(f)</code> to be converted to dummy variables.

**Value**

A `model.matrix` with dummy variables as columns.

**Examples**

```
data(Orthodont, package="nlme")
lmer(distance ~ age + (age|Subject) +
      (0+dummy(Sex, "Female")|Subject), data = Orthodont)
```

---

Dyestuff	<i>Yield of dyestuff by batch</i>
----------	-----------------------------------

---

**Description**

The `Dyestuff` data frame provides the yield of dyestuff (Naphthalene Black 12B) from 5 different preparations from each of 6 different batches of an intermediate product (H-acid). The `Dyestuff2` data were generated data in the same structure but with a large residual variance relative to the batch variance.

**Format**

Data frames, each with 30 observations on the following 2 variables.

`Batch` a factor indicating the batch of the intermediate product from which the preparation was created.

`Yield` the yield of dyestuff from the preparation (grams of standard color).

**Details**

The Dyestuff data are described in Davies and Goldsmith (1972) as coming from “an investigation to find out how much the variation from batch to batch in the quality of an intermediate product (H-acid) contributes to the variation in the yield of the dyestuff (Naphthalene Black 12B) made from it. In the experiment six samples of the intermediate, representing different batches of works manufacture, were obtained, and five preparations of the dyestuff were made in the laboratory from each sample. The equivalent yield of each preparation as grams of standard colour was determined by dye-trial.”

The Dyestuff2 data are described in Box and Tiao (1973) as illustrating “the case where between-batches mean square is less than the within-batches mean square. These data had to be constructed for although examples of this sort undoubtedly occur in practice, they seem to be rarely published.”

**Source**

O.L. Davies and P.L. Goldsmith (eds), *Statistical Methods in Research and Production*, 4th ed., Oliver and Boyd, (1972), section 6.4

G.E.P. Box and G.C. Tiao, *Bayesian Inference in Statistical Analysis*, Addison-Wesley, (1973), section 5.1.2

**Examples**

```
require(lattice)
str(Dyestuff)
dotplot(reorder(Batch, Yield) ~ Yield, Dyestuff,
        ylab = "Batch", jitter.y = TRUE, aspect = 0.3,
        type = c("p", "a"))
dotplot(reorder(Batch, Yield) ~ Yield, Dyestuff2,
        ylab = "Batch", jitter.y = TRUE, aspect = 0.3,
        type = c("p", "a"))
(fm1 <- lmer(Yield ~ 1|Batch, Dyestuff))
(fm2 <- lmer(Yield ~ 1|Batch, Dyestuff2))
```

---

expandDoubleVerts      *Expand terms with '||' notation into separate '|' terms*

---

**Description**

From the right hand side of a formula for a mixed-effects model, expand terms with the double vertical bar operator into separate, independent random effect terms.

**Usage**

```
expandDoubleVerts(term)
```

**Arguments**

term                    a mixed-model formula

**Value**

the modified term

**Note**

Because `||` works at the level of formula parsing, it has no way of knowing whether a variable is a factor. It just takes the terms within a random-effects term and literally splits them into the intercept and separate no-intercept terms, e.g.  $(1+x+y|f)$  would be split into  $(1|f) + (0+x|f) + (0+y|f)$ . However, `||` will fail to break up factors into separate terms; the `dummy` function can be useful in this case, although it is not as convenient as `||`.

**See Also**

[formula](#), [model.frame](#), [model.matrix](#), [dummy](#).

Other utilities: [mkRespMod](#), [mkReTrms](#), [nlformula](#), [nobars](#), [subbars](#)

**Examples**

```
m <- ~ x + (x || g)
expandDoubleVerts(m)
set.seed(101)
dd <- expand.grid(f=factor(letters[1:3]),g=factor(1:200),rep=1:3)
dd$y <- simulate(~f + (1|g) + (0+dummy(f,"b")|g) + (0+dummy(f,"c")|g),
  newdata=dd,
  newparams=list(beta=rep(0,3),
                 theta=c(1,2,1),
                 sigma=1),
  family=gaussian)[[1]]
m1 <- lmer(y~f+(f|g),data=dd)
VarCorr(m1)
m2 <- lmer(y~f+(1|g) + (0+dummy(f,"b")|g) + (0+dummy(f,"c")|g),
  data=dd)
VarCorr(m2)
```

---

factorize

*Attempt to convert grouping variables to factors*

---

**Description**

If variables within a data frame are not factors, try to convert them. Not intended for end-user use; this is a utility function that needs to be exported, for technical reasons.

**Usage**

```
factorize(x, frloc, char.only=FALSE)
```

**Arguments**

x	a formula
frloc	a data frame
char.only	(logical) convert only character variables to factors?

**Value**

a copy of the data frame with factors converted

---

findbars	<i>Determine random-effects expressions from a formula</i>
----------	--

---

**Description**

From the right hand side of a formula for a mixed-effects model, determine the pairs of expressions that are separated by the vertical bar operator. Also expand the slash operator in grouping factor expressions and expand terms with the double vertical bar operator into separate, independent random effect terms.

**Usage**

```
findbars(term)
```

**Arguments**

term	a mixed-model formula
------	-----------------------

**Value**

pairs of expressions that were separated by vertical bars

**Note**

This function is called recursively on individual terms in the model, which is why the argument is called `term` and not a name like `form`, indicating a formula.

**See Also**

[formula](#), [model.frame](#), [model.matrix](#).

Other utilities: [mkRespMod](#), [mkReTrms](#), [nlformula](#), [nobars](#), [subbars](#)

**Examples**

```

findbars(f1 <- Reaction ~ Days + (Days | Subject))
## => list( Days | Subject )
## These two are equivalent:% tests in ../inst/tests/test-doubleVertNotation.R
findbars(y ~ Days + (1 | Subject) + (0 + Days | Subject))
findbars(y ~ Days + (Days || Subject))
## => list of length 2: list ( 1 | Subject , 0 + Days | Subject)
findbars(~ 1 + (1 | batch / cask))
## => list of length 2: list ( 1 | cask:batch , 1 | batch)

```

---

fixef

*Extract fixed-effects estimates*


---

**Description**

Extract the fixed-effects estimates

**Usage**

```

## S3 method for class 'merMod'
fixef(object, add.dropped=FALSE, ...)

```

**Arguments**

object	any fitted model object from which fixed effects estimates can be extracted.
add.dropped	for models with rank-deficient design matrix, reconstitute the full-length parameter vector by adding NA values in appropriate locations?
...	optional additional arguments. Currently none are used in any methods.

**Details**

Extract the estimates of the fixed-effects parameters from a fitted model.

**Value**

a named, numeric vector of fixed-effects estimates.

**Examples**

```

fixef(lmer(Reaction ~ Days + (1|Subject) + (0+Days|Subject), sleepstudy))
fm2 <- lmer(Reaction ~ Days + Days2 + (1|Subject),
           data=transform(sleepstudy,Days2=Days))
fixef(fm2,add.dropped=TRUE)
## first two parameters are the same ...
stopifnot(all.equal(fixef(fm2,add.dropped=TRUE)[1:2],
                    fixef(fm2)))

```

---

fortify	<i>add information to data based on a fitted model</i>
---------	--

---

**Description**

add information to data based on a fitted model

**Usage**

```
fortify.merMod(model, data = getData(model),
  ...)
```

**Arguments**

model	fitted model
data	original data set, if needed
...	additional arguments

**Details**

fortify is a function defined in the **ggplot2** package, q.v. for more details. fortify is *not* defined here, and fortify.merMod is defined as a function rather than an S3 method, to avoid (1) inducing a dependency on **ggplot2** or (2) masking methods from **ggplot2**. This is currently an experimental feature.

---

getME	<i>Extract or Get Generalized Components from a Fitted Mixed Effects Model</i>
-------	--

---

**Description**

Extract (or “get”) “components” – in a generalized sense – from a fitted mixed-effects model, i.e., (in this version of the package) from an object of class “merMod”.

**Usage**

```
getME(object, name, ...)

## S3 method for class 'merMod'
getME(object,
  name = c("X", "Z", "Zt", "Ztlist", "mmList", "y", "mu", "u", "b",
    "Gp", "Tp", "L", "Lambda", "Lambdat", "Lind", "Tlist",
    "A", "RX", "RZX", "sigma", "flist",
    "fixef", "beta", "theta", "ST", "REML", "is_REML",
    "n_rtrms", "n_rfacs", "N", "n", "p", "q",
```

```
"p_i", "l_i", "q_i", "k", "m_i", "m",
"cnms", "devcomp", "offset", "lower", "devfun", "glmer.nb.theta"),
...)
```

## Arguments

**object** a fitted mixed-effects model of class `"merMod"`, i.e., typically the result of `lmer()`, `glmer()` or `nlmer()`.

**name** a character vector specifying the name(s) of the “component”. If `length(name) > 1` or if `name = "ALL"`, a named `list` of components will be returned. Possible values are:

`"X"`: fixed-effects model matrix

`"Z"`: random-effects model matrix

`"Zt"`: transpose of random-effects model matrix. Note that the structure of `Zt` has changed since `lme4.0`; to get a backward-compatible structure, use `do.call(Matrix::rBind, getME(., "Ztlist"))`

`"Ztlist"`: list of components of the transpose of the random-effects model matrix, separated by individual variance component

`"mmList"`: list of raw model matrices associated with random effects terms

`"y"`: response vector

`"mu"`: conditional mean of the response

`"u"`: conditional mode of the “spherical” random effects variable

`"b"`: conditional mode of the random effects variable

`"Gp"`: groups pointer vector. A pointer to the beginning of each group of random effects corresponding to the random-effects terms, beginning with 0 and including a final element giving the total number of random effects

`"Tp"`: theta pointer vector. A pointer to the beginning of the theta sub-vectors corresponding to the random-effects terms, beginning with 0 and including a final element giving the number of thetas.

`"L"`: sparse Cholesky factor of the penalized random-effects model.

`"Lambda"`: relative covariance factor  $\Lambda$  of the random effects.

`"Lambdat"`: transpose  $\Lambda'$  of  $\Lambda$  above.

`"Lind"`: index vector for inserting elements of  $\theta$  into the nonzeros of  $\Lambda$ .

`"Tlist"`: vector of template matrices from which the blocks of  $\Lambda$  are generated.

`"A"`: Scaled sparse model matrix (class `"dgCMatrix"`) for the unit, orthogonal random effects,  $U$ , equal to `getME(., "Zt") %*% getME(., "Lambdat")`

`"RX"`: Cholesky factor for the fixed-effects parameters

`"RZX"`: cross-term in the full Cholesky factor

`"sigma"`: residual standard error; note that `sigma(object)` is preferred.

`"flist"`: a list of the grouping variables (factors) involved in the random effect terms

`"fixef"`: fixed-effects parameter estimates

`"beta"`: fixed-effects parameter estimates (identical to the result of `fixef`, but without names)



"theta": random-effects parameter estimates: these are parameterized as the relative Cholesky factors of each random effect term

"ST": A list of S and T factors in the TSST Cholesky factorization of the relative variance matrices of the random effects associated with each random-effects term. The unit lower triangular matrix,  $T$ , and the diagonal matrix,  $S$ , for each term are stored as a single matrix with diagonal elements from  $S$  and off-diagonal elements from  $T$ .

"n\_rtrms": number of random-effects terms

"n\_rfacs": number of distinct random-effects grouping factors

"N": number of rows of  $X$

"n": length of the response vector,  $y$

"p": number of columns of the fixed effects model matrix,  $X$

"q": number of columns of the random effects model matrix,  $Z$

"p\_i": numbers of columns of the raw model matrices, `mmlist`

"l\_i": numbers of levels of the grouping factors

"q\_i": numbers of columns of the term-wise model matrices, `ZtList`

"k": number of random effects terms

"m\_i": numbers of covariance parameters in each term

"m": total number of covariance parameters

"cnms": the "component names", a `list`.

"REML": 0 indicates the model was fitted by maximum likelihood, any other positive integer indicates fitting by restricted maximum likelihood

"is\_REML": same as the result of `isREML(.)`

"devcomp": a list consisting of a named numeric vector, `cmp`, and a named integer vector, `dims`, describing the fitted model. The elements of `cmp` are:

**ldL2** twice the log determinant of  $L$

**ldRX2** twice the log determinant of  $RX$

**wrss** weighted residual sum of squares

**ussq** squared length of  $u$

**pwrss** penalized weighted residual sum of squares, "wrss + ussq"

**drsum** sum of residual deviance (GLMMs only)

**REML** REML criterion at optimum (LMMs fit by REML only)

**dev** deviance criterion at optimum (models fit by ML only)

**sigmaML** ML estimate of residual standard deviation

**sigmaREML** REML estimate of residual standard deviation

**tolPwrss** tolerance for declaring convergence in the penalized iteratively weighted residual sum-of-squares (GLMMs only)

The elements of `dims` are:

**N** number of rows of  $X$

**n** length of  $y$

**p** number of columns of  $X$

**nmp**  $n-p$

**nth** length of theta  
**q** number of columns of Z  
**nAGQ** see [glmer](#)  
**compDev** see [glmerControl](#)  
**useSc** TRUE if model has a scale parameter  
**reTrms** number of random effects terms  
**REML** 0 indicates the model was fitted by maximum likelihood, any other positive integer indicates fitting by restricted maximum likelihood  
**GLMM** TRUE if a GLMM  
**NLMM** TRUE if an NLMM  
**"offset"**: model offset  
**"lower"**: lower bounds on model parameters (random effects parameters only).  
**"devfun"**: deviance function (so far only available for LMMs)  
**"glmer.nb.theta"**: negative binomial  $\theta$  parameter, only for [glmer.nb](#).  
**"ALL"**: get all of the above as a [list](#).  
 ... currently unused in **lme4**, potentially further arguments in methods.

### Details

The goal is to provide “everything a user may want” from a fitted “merMod” object *as far* as it is not available by methods, such as [fixef](#), [ranef](#), [vcov](#), etc.

### Value

Unspecified, as very much depending on the [name](#).

### See Also

[getCall\(\)](#). More standard methods for “merMod” objects, such as [ranef](#), [fixef](#), [vcov](#), etc.: see [methods\(class="merMod"\)](#)

### Examples

```

## shows many methods you should consider *before* using getME():
methods(class = "merMod")

(fm1 <- lmer(Reaction ~ Days + (Days|Subject), sleepstudy))
Z <- getME(fm1, "Z")
stopifnot(is(Z, "CsparseMatrix"),
          c(180,36) == dim(Z),
          all.equal(fixef(fm1), b1 <- getME(fm1, "beta"),
                    check.attributes=FALSE, tolerance = 0))

## A way to get *all* getME()s :
## internal consistency check ensuring that all work:
parts <- getME(fm1, "ALL")
str(parts, max=2)
stopifnot(identical(Z, parts $ Z),
          identical(b1, parts $ beta))

```

---

GHrule

*Univariate Gauss-Hermite quadrature rule*

---

## Description

Create a univariate Gauss-Hermite quadrature rule.

## Usage

```
GHrule(ord, asMatrix = TRUE)
```

## Arguments

ord	scalar integer between 1 and 25 - the order, or number of nodes and weights, in the rule. When the function being multiplied by the standard normal density is a polynomial of order $2k-1$ the rule of order $k$ integrates the product exactly.
asMatrix	logical scalar - should the result be returned as a matrix. If FALSE a data frame is returned. Defaults to TRUE.

## Details

This version of Gauss-Hermite quadrature provides the node positions and weights for a scalar integral of a function multiplied by the standard normal density.

Originally based on package **SparseGrid**'s hidden `GQN()`.

## Value

a matrix (or data frame, if `asMatrix` is false) with `ord` rows and three columns which are `z` the node positions, `w` the weights and `ldnorm`, the logarithm of the normal density evaluated at the nodes.

## See Also

a different interface is available via [GQdk\(\)](#).

## Examples

```
(r5 <- GHrule(5, asMatrix=FALSE))
## second, fourth, sixth, eighth and tenth central moments of the
## standard Gaussian density
with(r5, sapply(seq(2, 10, 2), function(p) sum(w * z^p)))
```

glmer

*Fitting Generalized Linear Mixed-Effects Models***Description**

Fit a generalized linear mixed-effects model (GLMM). Both fixed effects and random effects are specified via the model formula.

**Usage**

```
glmer(formula, data = NULL, family = gaussian, control = glmerControl(),
      start = NULL, verbose = 0L, nAGQ = 1L, subset, weights, na.action,
      offset, contrasts = NULL, mustart, etastart,
      devFunOnly = FALSE, ...)
```

**Arguments**

- |         |  |
|---------|--|
| formula | a two-sided linear formula object describing both the fixed-effects and fixed-effects part of the model, with the response on the left of a <code>~</code> operator and the terms, separated by <code>+</code> operators, on the right. Random-effects terms are distinguished by vertical bars (" <code> </code> ") separating expressions for design matrices from grouping factors.   |
| data    | an optional data frame containing the variables named in formula. By default the variables are taken from the environment from which <code>lmer</code> is called. While data is optional, the package authors <i>strongly</i> recommend its use, especially when later applying methods such as <code>update</code> and <code>drop1</code> to the fitted model ( <i>such methods are not guaranteed to work properly if data is omitted</i> ). If data is omitted, variables will be taken from the environment of formula (if specified as a formula) or from the parent frame (if specified as a character vector).  |
| family  | a GLM family, see <code>glm</code> and <code>family</code> .   |
| control | a list (of correct class, resulting from <code>lmerControl()</code> or <code>glmerControl()</code> respectively) containing control parameters, including the nonlinear optimizer to be used and parameters to be passed through to the nonlinear optimizer, see the <code>*lmerControl</code> documentation for details.  |
| start   | a named list of starting values for the parameters in the model, or a numeric vector. A numeric <code>start</code> argument will be used as the starting value of theta. If <code>start</code> is a list, the <code>theta</code> element (a numeric vector) is used as the starting value for the first optimization step (default=1 for diagonal elements and 0 for off-diagonal elements of the lower Cholesky factor); the fitted value of theta from the first step, plus <code>start[["fixef"]]</code> , are used as starting values for the second optimization step. If <code>start</code> has both <code>fixef</code> and <code>theta</code> elements, the first optimization step is skipped. For more details or finer control of optimization, see <code>modular</code> . |
| verbose | integer scalar. If <code>&gt; 0</code> verbose output is generated during the optimization of the parameter estimates. If <code>&gt; 1</code> verbose output is generated during the individual PIRLS steps.   |

nAGQ	integer scalar - the number of points per axis for evaluating the adaptive Gauss-Hermite approximation to the log-likelihood. Defaults to 1, corresponding to the Laplace approximation. Values greater than 1 produce greater accuracy in the evaluation of the log-likelihood at the expense of speed. A value of zero uses a faster but less exact form of parameter estimation for GLMMs by optimizing the random effects and the fixed-effects coefficients in the penalized iteratively reweighted least squares step. (See Details.)
subset	an optional expression indicating the subset of the rows of data that should be used in the fit. This can be a logical vector, or a numeric vector indicating which observation numbers are to be included, or a character vector of the row names to be included. All observations are included by default.
weights	an optional vector of 'prior weights' to be used in the fitting process. Should be NULL or a numeric vector.
na.action	a function that indicates what should happen when the data contain NAs. The default action ( <code>na.omit</code> , inherited from the 'factory fresh' value of <code>getOption("na.action")</code> ) strips any observations with any missing values in any variables.
offset	this can be used to specify an <i>a priori</i> known component to be included in the linear predictor during fitting. This should be NULL or a numeric vector of length equal to the number of cases. One or more <code>offset</code> terms can be included in the formula instead or as well, and if more than one is specified their sum is used. See <code>model.offset</code> .
contrasts	an optional list. See the <code>contrasts.arg</code> of <code>model.matrix.default</code> .
mustart	optional starting values on the scale of the conditional mean, as in <code>glm</code> ; see there for details.
etastart	optional starting values on the scale of the unbounded predictor as in <code>glm</code> ; see there for details.
devFunOnly	logical - return only the deviance evaluation function. Note that because the deviance function operates on variables stored in its environment, it may not return <i>exactly</i> the same values on subsequent calls (but the results should always be within machine tolerance).
...	other potential arguments. A <code>method</code> argument was used in earlier versions of the package. Its functionality has been replaced by the <code>nAGQ</code> argument.

## Details

Fit a generalized linear mixed model, which incorporates both fixed-effects parameters and random effects in a linear predictor, via maximum likelihood. The linear predictor is related to the conditional mean of the response through the inverse link function defined in the GLM family.

The expression for the likelihood of a mixed-effects model is an integral over the random effects space. For a linear mixed-effects model (LMM), as fit by `lmer`, this integral can be evaluated exactly. For a GLMM the integral must be approximated. The most reliable approximation for GLMMs is adaptive Gauss-Hermite quadrature, at present implemented only for models with a single scalar random effect. The `nAGQ` argument controls the number of nodes in the quadrature formula. A model with a single, scalar random-effects term could reasonably use up to 25 quadrature points per scalar integral.

**Value**

An object of class `merMod` (more specifically, an object of *subclass* `glmerMod`) for which many methods are available (e.g. `methods(class="merMod")`)

**See Also**

`lmer` (for details on formulas and parameterization); `glm` for Generalized Linear Models (*without* random effects). `nlmer` for nonlinear mixed-effects models.

`glmer.nb` to fit negative binomial GLMMs.

**Examples**

```
## generalized linear mixed model
library(lattice)
xyplot(incidence/size ~ period|herd, cbpp, type=c('g','p','l'),
       layout=c(3,5), index.cond = function(x,y)max(y))
(gm1 <- glmer(cbind(incidence, size - incidence) ~ period + (1 | herd),
             data = cbpp, family = binomial))
## using nAGQ=0 only gets close to the optimum
(gm1a <- glmer(cbind(incidence, size - incidence) ~ period + (1 | herd),
             cbpp, binomial, nAGQ = 0))
## using nAGQ = 9 provides a better evaluation of the deviance
## Currently the internal calculations use the sum of deviance residuals,
## which is not directly comparable with the nAGQ=0 or nAGQ=1 result.
(gm1a <- glmer(cbind(incidence, size - incidence) ~ period + (1 | herd),
             cbpp, binomial, nAGQ = 9))

## GLMM with individual-level variability (accounting for overdispersion)
## For this data set the model is the same as one allowing for a period:herd
## interaction, which the plot indicates could be needed.
cbpp$obs <- 1:nrow(cbpp)
(gm2 <- glmer(cbind(incidence, size - incidence) ~ period +
             (1 | herd) + (1|obs),
             family = binomial, data = cbpp))
anova(gm1,gm2)

## glmer and glm log-likelihoods are consistent
gm1Devfun <- update(gm1,devFunOnly=TRUE)
gm0 <- glm(cbind(incidence, size - incidence) ~ period,
          family = binomial, data = cbpp)
## evaluate GLMM deviance at RE variance=theta=0, beta=(GLM coeffs)
gm1Dev0 <- gm1Devfun(c(0,coef(gm0)))
## compare
stopifnot(all.equal(gm1Dev0,c(-2*logLik(gm0))))
## the toenail oncholysis data from Backer et al 1998
## these data are notoriously difficult to fit
## Not run:
if (require("HSAUR2")) {
  gm2 <- glmer(outcome~treatment*visit+(1|patientID),
              data=toenail,
              family=binomial,nAGQ=20)
```

```

}
## End(Not run)

```

---

glmer.nb

*Fitting Negative Binomial GLMMs*


---

## Description

Fits a generalized linear mixed-effects model (GLMM) for the negative binomial family, building on [glmer](#), and initializing via [theta.ml](#) from **MASS**.

## Usage

```

glmer.nb(..., interval = log(th) + c(-3, 3),
          tol = 5e-5, verbose = FALSE, nb.control = NULL,
          initCtrl = list(limit = 20, eps = 2*tol, trace = verbose))

```

## Arguments

...	arguments as for <code>glmer(.)</code> such as formula, data, control, etc, but <i>not</i> family!
interval	interval in which to start the optimization. The default is symmetric on log scale around the initially estimated theta.
tol	tolerance for the optimization via <a href="#">optimize</a> .
verbose	<b>logical</b> indicating how much progress information should be printed during the optimization. Use <code>verbose = 2</code> (or larger) to enable <code>verbose=TRUE</code> in the <code>glmer()</code> calls.
nb.control	optional <b>list</b> , like <code>glmerControl()</code> , used in <code>refit(*, control = control.nb)</code> during the optimization.
initCtrl	<i>(experimental, do not rely on this:)</i> a <b>list</b> with named components as in the default, passed to <a href="#">theta.ml</a> (package <b>MASS</b> ) for the initial value of the negative binomial parameter theta.

## Value

An object of class `glmerMod`, for which many methods are available (e.g. `methods(class="glmerMod")`), see [glmer](#).

## Note

For historical reasons, the shape parameter of the negative binomial and the random effects parameters in our (G)LMM models are both called theta ( $\theta$ ), but are unrelated here.

The negative binomial  $\theta$  can be extracted from a fit `g <- glmer.nb()` by `getME(g, "glmer.nb.theta")`.

Parts of `glmer.nb()` are still experimental and methods are still missing or suboptimal. In particular, there is no inference available for the dispersion parameter  $\theta$ , yet.

**See Also**

[glmer](#); from package **MASS**, [negative.binomial](#) (which we re-export currently) and [theta.ml](#), the latter for initialization of optimization.

The ‘Details’ of [pnbinom](#) for the definition of the negative binomial distribution.

**Examples**

```
set.seed(101)
dd <- expand.grid(f1 = factor(1:3),
                 f2 = LETTERS[1:2], g=1:9, rep=1:15,
                 KEEP.OUT.ATTRS=FALSE)
summary(mu <- 5*(-4 + with(dd, as.integer(f1) + 4*as.numeric(f2))))
dd$y <- rnbinom(nrow(dd), mu = mu, size = 0.5)
str(dd)
require("MASS")## and use its glm.nb() - as indeed we have zero random effect:
## Not run:
m.glm <- glm.nb(y ~ f1*f2, data=dd, trace=TRUE)
summary(m.glm)
m.nb <- glmer.nb(y ~ f1*f2 + (1|g), data=dd, verbose=TRUE)
m.nb
## The neg.binomial theta parameter:
getME(m.nb, "glmer.nb.theta")
LL <- logLik(m.nb)
## mixed model has 1 additional parameter (RE variance)
stopifnot(attr(LL,"df")==attr(logLik(m.glm),"df")+1)
plot(m.nb, resid(.) ~ g)# works, as long as data 'dd' is found

## End(Not run)
```

---

glmerLaplaceHandle      *Handle for glmerLaplace*

---

**Description**

Handle for calling the glmerLaplace C++ function. Not intended for routine use.

**Usage**

```
glmerLaplaceHandle(pp, resp, nAGQ, tol, maxit, verbose)
```

**Arguments**

pp	<a href="#">merPredD</a> object
resp	<a href="#">lmResp</a> object
nAGQ	see <a href="#">glmer</a>
tol	tolerance
maxit	maximum number of pwrss iterations
verbose	display optimizer progress



**Value**

Value of the objective function

---

glmFamily	<i>Generator object for the <a href="#">glmFamily</a> class</i>
-----------	---

---

**Description**

The generator object for the [glmFamily](#) reference class. Such an object is primarily used through its new method.

**Usage**

```
glmFamily(...)
```

**Arguments**

...                   Named argument (see Note below)

**Methods**

new(family=family) Create a new [glmFamily](#) object

**Note**

Arguments to the new method must be named arguments.

**See Also**

[glmFamily](#)

---

glmFamily-class	<i>Class "glmFamily" - a reference class for <a href="#">family</a></i>
-----------------	---

---

**Description**

This class is a wrapper class for [family](#) objects specifying a distribution family and link function for a generalized linear model ([glm](#)). The reference class contains an external pointer to a C++ object representing the class. For common families and link functions the functions in the family are implemented in compiled code so they can be accessed from other compiled code and for a speed boost.

**Extends**

All reference classes extend and inherit methods from "[envRefClass](#)".

**Note**

Objects from this reference class correspond to objects in a C++ class. Methods are invoked on the C++ class using the external pointer in the `Ptr` field. When saving such an object the external pointer is converted to a null pointer, which is why there is a redundant field `ptr` that is an active-binding function returning the external pointer. If the `Ptr` field is a null pointer, the external pointer is regenerated for the stored `family` field.

**See Also**

[family](#), [glmFamily](#)

**Examples**

```
str(glmFamily$new(family=poisson()))
```

---

golden-class

*Class "golden" and Generator for Golden Search Optimizer Class*

---

**Description**

"golden" is a reference class for a golden search scalar optimizer, for a parameter within an interval. `golden()` is the generator for the "golden" class. The optimizer uses reverse communications.

**Usage**

```
golden(...)
```

**Arguments**

... (partly optional) arguments passed to `new()` must be named arguments. `lower` and `upper` are the bounds for the scalar parameter; they must be finite.

**Extends**

All reference classes extend and inherit methods from "[envRefClass](#)".

**Examples**

```
showClass("golden")
```

```
golden(lower= -100, upper= 1e100)
```

---

GQdk

*Sparse Gaussian / Gauss-Hermite Quadrature grid*


---

**Description**

Generate the sparse multidimensional Gaussian quadrature grids.

Currently unused. See [GHrule\(\)](#) for the version currently in use in package **lme4**.

**Usage**

```
GQdk(d = 1L, k = 1L)
GQN
```

**Arguments**

**d** integer scalar - the dimension of the function to be integrated with respect to the standard d-dimensional Gaussian density.

**k** integer scalar - the order of the grid. A grid of order k provides an exact result for a polynomial of total order of  $2k - 1$  or less.

**Value**

GQdk() returns a matrix with  $d + 1$  columns. The first column is the weights and the remaining d columns are the node coordinates.

GQN is a [list](#) of lists, containing the non-redundant quadrature nodes and weights for integration of a scalar function of a d-dimensional argument with respect to the density function of the d-dimensional Gaussian density function.

The outer list is indexed by the dimension, d, in the range of 1 to 20. The inner list is indexed by k, the order of the quadrature.

**Note**

GQN contains only the non-redundant nodes. To regenerate the whole array of nodes, all possible permutations of axes and all possible combinations of  $\pm 1$  must be applied to the axes. This entire array of nodes is exactly what [GQdk\(\)](#) reproduces.

The number of nodes gets very large very quickly with increasing d and k. See the charts at <http://www.sparse-grids.de>.

**Examples**

```
GQdk(2,5) # 53 x 3
```

```
GQN[[3]][[5]] # a 14 x 4 matrix
```

---

grouseticks

*Data on red grouse ticks from Elston et al. 2001*

---

## Description

Number of ticks on the heads of red grouse chicks sampled in the field (grouseticks) and an aggregated version (grouseticks\_agg); see original source for more details

## Usage

```
data(grouseticks)
```

## Format

INDEX (factor) chick number (observation level)

TICKS number of ticks sampled

BROOD (factor) brood number

HEIGHT height above sea level (meters)

YEAR year (-1900)

LOCATION (factor) geographic location code

cHEIGHT centered height, derived from HEIGHT

meanTICKS mean number of ticks by brood

varTICKS variance of number of ticks by brood

## Details

grouseticks\_agg is just a brood-level aggregation of the data

## Source

Robert Moss, via David Elston

## References

Elston, D. A., R. Moss, T. Boulinier, C. Arrowsmith, and X. Lambin. 2001. "Analysis of Aggregation, a Worked Example: Numbers of Ticks on Red Grouse Chicks." *Parasitology* 122 (05): 563-569. doi:10.1017/S0031182001007740. <http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=82701>.

**Examples**

```

data(grouseticks)
## Figure 1a from Elston et al
par(las=1,bty="l")
tvec <- c(0,1,2,5,20,40,80)
pvec <- c(4,1,3)
with(grouseticks_agg,plot(1+meanTICKS~HEIGHT,
                        pch=pvec[factor(YEAR)],
                        log="y",axes=FALSE,
                        xlab="Altitude (m)",
                        ylab="Brood mean ticks"))

axis(side=1)
axis(side=2,at=tvec+1,label=tvec)
box()
abline(v=405,lty=2)
## Figure 1b
with(grouseticks_agg,plot(varTICKS~meanTICKS,
                        pch=4,
                        xlab="Brood mean ticks",
                        ylab="Within-brood variance"))
curve(1*x,from=0,to=70,add=TRUE)
## Model fitting
form <- TICKS~YEAR+HEIGHT+(1|BROOD)+(1|INDEX)+(1|LOCATION)
(full_mod1 <- glmer(form, family="poisson",data=grouseticks))

```

---

hatvalues.merMod

*Diagonal elements of the hat matrix*


---

**Description**

Returns the values on the diagonal of the hat matrix, which is the matrix that transforms the response vector (minus any offset) into the fitted values (minus any offset). Note that this method should only be used for linear mixed models. It is not clear if the hat matrix concept even makes sense for generalized linear mixed models.

**Usage**

```

## S3 method for class 'merMod'
hatvalues(model, fullHatMatrix = FALSE, ...)

```

**Arguments**

model	An object of class <code>merMod</code> .
fullHatMatrix	Return full hat matrix (not just diagonal values)?
...	Not currently used

**Value**

The diagonal elements of the hat matrix.

**Examples**

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

---

InstEval

*University Lecture/Instructor Evaluations by Students at ETH*


---

**Description**

University lecture evaluations by students at ETH Zurich, anonymized for privacy protection. This is an interesting “medium” sized example of a *partially* nested mixed effect model.

**Format**

A data frame with 73421 observations on the following 7 variables.

`s` a factor with levels 1:2972 denoting individual students.

`d` a factor with 1128 levels from 1:2160, denoting individual professors or lecturers.

`studage` an ordered factor with levels 2 < 4 < 6 < 8, denoting student’s “age” measured in the *semester* number the student has been enrolled.

`lectage` an ordered factor with 6 levels, 1 < 2 < ... < 6, measuring how many semesters back the lecture rated had taken place.

`service` a binary factor with levels 0 and 1; a lecture is a “service”, if held for a different department than the lecturer’s main one.

`dept` a factor with 14 levels from 1:15, using a random code for the department of the lecture.

`y` a numeric vector of *ratings* of lectures by the students, using the discrete scale 1:5, with meanings of ‘poor’ to ‘very good’.

Each observation is one student’s rating for a specific lecture (of one lecturer, during one semester in the past).

**Details**

The main goal of the survey is to find “the best liked prof”, according to the lectures given. Statistical analysis of such data has been the basis for a (student) jury selecting the final winners.

The present data set has been anonymized and slightly simplified on purpose.

**Examples**

```
str(InstEval)
```

```
head(InstEval, 16)
```

```
xtabs(~ service + dept, InstEval)
```

---

isNested	<i>Is f1 nested within f2?</i>
----------	--------------------------------

---

**Description**

Does every level of f1 occur in conjunction with exactly one level of f2? The function is based on converting a triplet sparse matrix to a compressed column-oriented form in which the nesting can be quickly evaluated.

**Usage**

```
isNested(f1, f2)
```

**Arguments**

f1	factor 1
f2	factor 2

**Value**

TRUE if factor 1 is nested within factor 2

**Examples**

```
with(Pastes, isNested(cask, batch)) ## => FALSE
with(Pastes, isNested(sample, batch)) ## => TRUE
```

---

isREML	<i>Check characteristics of models</i>
--------	--

---

**Description**

Check characteristics of models: whether a model fit corresponds to a linear (LMM), generalized linear (GLMM), or nonlinear (NLMM) mixed model, and whether a linear mixed model has been fitted by REML or not (isREML(x) is always FALSE for GLMMs and NLMMs).

**Usage**

```
isREML(x, ...)
isLMM(x, ...)
isNLMM(x, ...)
isGLMM(x, ...)
```

**Arguments**

`x` a fitted model.  
`...` additional, optional arguments. (None are used in the `merMod` methods)

**Details**

These are generic functions. At present the only methods are for mixed-effects models of class `merMod`.

**Value**

a logical value

**See Also**

`getME`

**Examples**

```
fm1 <- lmer(Reaction ~ Days + (Days|Subject), sleepstudy)
gm1 <- glmer(cbind(incidence, size - incidence) ~ period + (1 | herd),
            data = cbpp, family = binomial)
nm1 <- nlmer(circumference ~ SSlogis(age, Asym, xmid, scal) ~ Asym|Tree,
            Orange, start = c(Asym = 200, xmid = 725, scal = 350))

isLMM(fm1)
isGLMM(gm1)
## check all :
is.MM <- function(x) c(LMM = isLMM(x), GLMM= isGLMM(x), NLMM= isNLMM(x))
stopifnot(cbind(is.MM(fm1), is.MM(gm1), is.MM(nm1))
          == diag(rep(TRUE,3)))
```

---

lmer

*Fit Linear Mixed-Effects Models*


---

**Description**

Fit a linear mixed-effects model (LMM) to data, via REML or maximum likelihood.

**Usage**

```
lmer(formula, data = NULL, REML = TRUE, control = lmerControl(),
      start = NULL, verbose = 0L, subset, weights, na.action,
      offset, contrasts = NULL, devFunOnly = FALSE, ...)
```



**Arguments**

formula	a two-sided linear formula object describing both the fixed-effects and random-effects part of the model, with the response on the left of a <code>~</code> operator and the terms, separated by <code>+</code> operators, on the right. Random-effects terms are distinguished by vertical bars ( <code> </code> ) separating expressions for design matrices from grouping factors. Two vertical bars ( <code>  </code> ) can be used to specify multiple uncorrelated random effects for the same grouping variable. (Because of the way it is implemented, the <code>  </code> -syntax <i>works only for design matrices containing numeric (continuous) predictors</i> ; to fit models with independent categorical effects, see <a href="#">dummy</a> or the <code>lmer_alt</code> function from the <code>afex</code> package.)
data	an optional data frame containing the variables named in <code>formula</code> . By default the variables are taken from the environment from which <code>lmer</code> is called. While <code>data</code> is optional, the package authors <i>strongly</i> recommend its use, especially when later applying methods such as <code>update</code> and <code>drop1</code> to the fitted model ( <i>such methods are not guaranteed to work properly if data is omitted</i> ). If <code>data</code> is omitted, variables will be taken from the environment of <code>formula</code> (if specified as a formula) or from the parent frame (if specified as a character vector).
REML	logical scalar - Should the estimates be chosen to optimize the REML criterion (as opposed to the log-likelihood)?
control	a list (of correct class, resulting from <code>lmerControl()</code> or <code>glmerControl()</code> respectively) containing control parameters, including the nonlinear optimizer to be used and parameters to be passed through to the nonlinear optimizer, see the <code>*lmerControl</code> documentation for details.
start	a named <a href="#">list</a> of starting values for the parameters in the model. For <code>lmer</code> this can be a numeric vector or a list with one component named <code>"theta"</code> .
verbose	integer scalar. If <code>&gt; 0</code> verbose output is generated during the optimization of the parameter estimates. If <code>&gt; 1</code> verbose output is generated during the individual PIRLS steps.
subset	an optional expression indicating the subset of the rows of <code>data</code> that should be used in the fit. This can be a logical vector, or a numeric vector indicating which observation numbers are to be included, or a character vector of the row names to be included. All observations are included by default.
weights	an optional vector of 'prior weights' to be used in the fitting process. Should be <code>NULL</code> or a numeric vector. Prior weights are <i>not</i> normalized or standardized in any way. In particular, the diagonal of the residual covariance matrix is the squared residual standard deviation parameter <code>sigma</code> times the vector of inverse weights. Therefore, if the weights have relatively large magnitudes, then in order to compensate, the <code>sigma</code> parameter will also need to have a relatively large magnitude.
na.action	a function that indicates what should happen when the data contain NAs. The default action ( <code>na.omit</code> , inherited from the 'factory fresh' value of <code>getOption("na.action")</code> ) strips any observations with any missing values in any variables.
offset	this can be used to specify an <i>a priori</i> known component to be included in the linear predictor during fitting. This should be <code>NULL</code> or a numeric vector of length equal to the number of cases. One or more <a href="#">offset</a> terms can be included in the

	formula instead or as well, and if more than one is specified their sum is used. See <a href="#">model.offset</a> .
contrasts	an optional list. See the <code>contrasts.arg</code> of <code>model.matrix.default</code> .
devFunOnly	logical - return only the deviance evaluation function. Note that because the deviance function operates on variables stored in its environment, it may not return <i>exactly</i> the same values on subsequent calls (but the results should always be within machine tolerance).
...	other potential arguments. A <code>method</code> argument was used in earlier versions of the package. Its functionality has been replaced by the <code>REML</code> argument.

### Details

- If the `formula` argument is specified as a character vector, the function will attempt to coerce it to a formula. However, this is not recommended (users who want to construct formulas by pasting together components are advised to use [as.formula](#) or [reformulate](#)); model fits will work but subsequent methods such as [drop1](#), [update](#) may fail.
- When handling perfectly collinear predictor variables (i.e. design matrices of less than full rank), `[gn]lmer` is not quite as sophisticated as some simpler modeling frameworks such as [lm](#) and [glm](#). While it does automatically drop collinear variables (with a message rather than a warning), it does not automatically fill in NA values for the dropped coefficients; these can be added via `fixef(fitted.model, add.dropped=TRUE)`. This information can also be retrieved via `attr(getME(fitted.model, "X"), "col.dropped")`.
- the deviance function returned when `devFunOnly` is TRUE takes a single numeric vector argument, representing the `theta` vector. This vector defines the scaled variance-covariance matrices of the random effects, in the Cholesky parameterization. For models with only simple (intercept-only) random effects, `theta` is a vector of the standard deviations of the random effects. For more complex or multiple random effects, running `getME(., "theta")` to retrieve the `theta` vector for a fitted model and examining the names of the vector is probably the easiest way to determine the correspondence between the elements of the `theta` vector and elements of the lower triangles of the Cholesky factors of the random effects.

### Value

An object of class `merMod` (more specifically, an object of *subclass* `lmerMod`), for which many methods are available (e.g. `methods(class="merMod")`)

### See Also

[lm](#) for linear models; [glmer](#) for generalized linear; and [nlmer](#) for nonlinear mixed models.

### Examples

```
## linear mixed models - reference values from older code
(fm1 <- lmer(Reaction ~ Days + (Days | Subject), sleepstudy))
summary(fm1) # (with its own print method; see class?merMod % ./merMod-class.Rd

str(terms(fm1))
stopifnot(identical(terms(fm1, fixed.only=FALSE),
```

```

      terms(model.frame(fm1)))
attr(terms(fm1, FALSE), "dataClasses") # fixed.only=FALSE needed for dataCl.

fm1_ML <- update(fm1, REML=FALSE)
(fm2 <- lmer(Reaction ~ Days + (Days || Subject), sleepstudy))
anova(fm1, fm2)
sm2 <- summary(fm2)
print(fm2, digits=7, ranef.comp="Var") # the print.merMod()          method
print(sm2, digits=3, corr=FALSE)      # the print.summary.merMod() method

(vv <- vcov.merMod(fm2, corr=TRUE))
as(vv, "corMatrix")# extracts the ("hidden") 'correlation' entry in @factors

## Fit sex-specific variances by constructing numeric dummy variables
## for sex and sex:age; in this case the estimated variance differences
## between groups in both intercept and slope are zero ...
data(Orthodont, package="nlme")
Orthodont$nsex <- as.numeric(Orthodont$Sex=="Male")
Orthodont$nsexage <- with(Orthodont, nsex*age)
lmer(distance ~ age + (age|Subject) + (0+nsex|Subject) +
      (0 + nsexage|Subject), data=Orthodont)

```

---

lmerControl

*Control of Mixed Model Fitting*


---

## Description

Construct control structures for mixed model fitting. All arguments have defaults, and can be grouped into

- general control parameters, most importantly optimizer, further restart\_edge, etc;
- model- or data-checking specifications, in short “checking options”, such as check.nobs.vs.rankZ, or check.rankX (currently not for nlmerControl);
- all the parameters to be passed to the optimizer, e.g., maximal number of iterations, passed via the optCtrl list argument.

## Usage

```

lmerControl(optimizer = "bobyqa",
  restart_edge = TRUE,
  boundary.tol = 1e-5,
  calc.derivs=TRUE,
  use.last.params=FALSE,
  sparseX = FALSE,
  ## input checking options
  check.nobs.vs.rankZ = "ignore",
  check.nobs.vs.nlev = "stop",
  check.nlev.gtreq.5 = "ignore",

```

```

check.nlev.gtr.1 = "stop",
check.nobs.vs.nRE="stop",
check.rankX = c("message+drop.cols", "silent.drop.cols", "warn+drop.cols",
               "stop.deficient", "ignore"),
check.scaleX = c("warning", "stop", "silent.rescale",
               "message+rescale", "warn+rescale", "ignore"),
check.formula.LHS = "stop",
## convergence checking options
check.conv.grad   = .makeCC("warning", tol = 2e-3, relTol = NULL),
check.conv.singular = .makeCC(action = "ignore", tol = 1e-4),
check.conv.hess    = .makeCC(action = "warning", tol = 1e-6),
## optimizer args
optCtrl = list()

glmerControl(optimizer = c("bobyqa", "Nelder_Mead"),
             restart_edge = FALSE,
             boundary.tol = 1e-5,
             calc.derivs=TRUE,
             use.last.params=FALSE,
             sparseX = FALSE,
             tolPwrss=1e-7,
             compDev=TRUE,
             nAGQ0initStep=TRUE,
             ## input checking options
             check.nobs.vs.rankZ = "ignore",
             check.nobs.vs.nlev = "stop",
             check.nlev.gtreq.5 = "ignore",
             check.nlev.gtr.1 = "stop",
             check.nobs.vs.nRE="stop",
             check.rankX = c("message+drop.cols", "silent.drop.cols", "warn+drop.cols",
                             "stop.deficient", "ignore"),
             check.scaleX = "warning",
             check.formula.LHS = "stop",
             check.response.not.const = "stop",
             ## convergence checking options
             check.conv.grad   = .makeCC("warning", tol = 1e-3, relTol = NULL),
             check.conv.singular = .makeCC(action = "ignore", tol = 1e-4),
             check.conv.hess    = .makeCC(action = "warning", tol = 1e-6),
             ## optimizer args
             optCtrl = list())

nlmerControl(optimizer = "Nelder_Mead", tolPwrss = 1e-10,
            optCtrl = list())

.makeCC(action, tol, relTol, ...)

```

**Arguments**

optimizer	<p>character - name of optimizing function(s). A character vector or list of functions: length 1 for lmer or glmer, possibly length 2 for glmer). The built-in optimizers are <a href="#">Nelder_Mead</a> and <a href="#">bobyqa</a> (from the <b>minqa</b> package). Any minimizing function that allows box constraints can be used provided that it</p> <ol style="list-style-type: none"> <li>(1) takes input parameters fn (function to be optimized), par (starting parameter values), lower (lower bounds) and control (control parameters, passed through from the control argument) and</li> <li>(2) returns a list with (at least) elements par (best-fit parameters), fval (best-fit function value), conv (convergence code, equal to zero for successful convergence) and (optionally) message (informational message, or explanation of convergence failure).</li> </ol> <p>Special provisions are made for <a href="#">bobyqa</a>, <a href="#">Nelder_Mead</a>, and optimizers wrapped in the <b>optimx</b> package; to use the <b>optimx</b> optimizers (including L-BFGS-B from base <a href="#">optim</a> and <a href="#">nlminb</a>), pass the method argument to optim in the optCtrl argument (you may also need to load the optimx package manually using <a href="#">library(optimx)</a> or <a href="#">require(optimx)</a>).</p> <p>For glmer, if length(optimizer)==2, the first element will be used for the preliminary (random effects parameters only) optimization, while the second will be used for the final (random effects plus fixed effect parameters) phase. See <a href="#">modular</a> for more information on these two phases.</p>
calc.derivs	logical - compute gradient and Hessian of nonlinear optimization solution?
use.last.params	logical - should the last value of the parameters evaluated (TRUE), rather than the value of the parameters corresponding to the minimum deviance, be returned? This is a "backward bug-compatibility" option; use TRUE only when trying to match previous results.
sparseX	logical - should a sparse model matrix be used for the fixed-effects terms? Currently inactive.
restart_edge	logical - should the optimizer attempt a restart when it finds a solution at the boundary (i.e. zero random-effect variances or perfect +/-1 correlations)? (Currently only implemented for lmerControl.)
boundary.tol	numeric - within what distance of a boundary should the boundary be checked for a better fit? (Set to zero to disable boundary checking.)
tolPwrss	numeric scalar - the tolerance for declaring convergence in the penalized iteratively weighted residual sum-of-squares step.
compDev	logical scalar - should compiled code be used for the deviance evaluation during the optimization of the parameter estimates?
nAGQ0initStep	do one initial run with nAGQ = 0.
check.nlev.gtr.5	character - rules for checking whether all random effects have >= 5 levels. See <a href="#">action</a> .
check.nlev.gtr.1	character - rules for checking whether all random effects have > 1 level. See <a href="#">action</a> .

- `check.nobs.vs.rankZ`  
 character - rules for checking whether the number of observations is greater than (or greater than or equal to) the rank of the random effects design matrix ( $Z$ ), usually necessary for identifiable variances. As for action, with the addition of "warningSmall" and "stopSmall", which run the test only if the dimensions of  $Z$  are  $< 1e6$ . `nobs > rank(Z)` will be tested for LMMs and GLMMs with estimated scale parameters; `nobs >= rank(Z)` will be tested for GLMMs with fixed scale parameter. The rank test is done using the `method="qr"` option of the `rankMatrix` function.
- `check.nobs.vs.nlev`  
 character - rules for checking whether the number of observations is less than (or less than or equal to) the number of levels of every grouping factor, usually necessary for identifiable variances. As for action. `nobs < nlevels` will be tested for LMMs and GLMMs with estimated scale parameters; `nobs <= nlevels` will be tested for GLMMs with fixed scale parameter.
- `check.nobs.vs.nRE`  
 character - rules for checking whether the number of observations is greater than (or greater than or equal to) the number of random-effects levels for each term, usually necessary for identifiable variances. As for `check.nobs.vs.nlev`.
- `check.conv.grad`  
 rules for checking the gradient of the deviance function for convergence. A list as returned by `.makeCC`, or a character string with only the action.
- `check.conv.singular`  
 rules for checking for a singular fit, i.e. one where some parameters are on the boundary of the feasible space (for example, random effects variances equal to 0 or correlations between random effects equal to  $\pm 1.0$ ); as for `check.conv.grad` above.
- `check.conv.hess`  
 rules for checking the Hessian of the deviance function for convergence.; as for `check.conv.grad` above.
- `check.rankX`  
 character - specifying if `rankMatrix(X)` should be compared with `ncol(X)` and if columns from the design matrix should possibly be dropped to ensure that it has full rank. Sometimes needed to make the model identifiable. The options can be abbreviated; the three `"*.drop.cols"` options all do drop columns, "stop.deficient" gives an error when the rank is smaller than the number of columns where "ignore" does no rank computation, and will typically lead to less easily understandable errors, later.
- `check.scaleX`  
 character - check for problematic scaling of columns of fixed-effect model matrix, e.g. parameters measured on very different scales.
- `check.formula.LHS`  
 check whether specified formula has a left-hand side. Primarily for internal use within `simulate.merMod`; *use at your own risk* as it may allow the generation of unstable `merMod` objects
- `check.response.not.const`  
 character - check that the response is not constant.
- `optCtrl`  
 a list of additional arguments to be passed to the nonlinear optimizer (see [Nelder\\_Mead](#), [bobyqa](#)). In particular, both `Nelder_Mead` and `bobyqa` use `maxfun`

	to specify the maximum number of function evaluations they will try before giving up - in contrast to <code>optim</code> and <code>optimx</code> -wrapped optimizers, which use <code>maxit</code> .
<code>action</code>	character - generic choices for the severity level of any test. "ignore": skip the test. "warning": warn if test fails. "stop": throw an error if test fails.
<code>tol</code>	numeric - tolerance for check
<code>relTol</code>	numeric - tolerance for checking relative variation
<code>...</code>	other elements to include in check specification

### Details

Note that (only!) the pre-fitting “checking options” (i.e., all those starting with “`check.`” but *not* including the convergence checks (“`check.conv.*`”) or rank-checking (“`check.rank*`”) options) may also be set globally via `options`. In that case, (g)lmerControl will use them rather than the default values, but will *not* override values that are passed as explicit arguments.

For example, `options(lmerControl=list(check.nobs.vs.rankZ = "ignore"))` will suppress warnings that the number of observations is less than the rank of the random effects model matrix Z.

### Value

The `*Control` functions return a list (inheriting from class “`merControl`”) containing

1. general control parameters, such as `optimizer`, `restart_edge`;
2. (currently not for `nlmerControl`!) “`checkControl`”, a `list` of data-checking specifications, e.g., `check.nobs.vs.rankZ`;
3. parameters to be passed to the optimizer, i.e., the `optCtrl` list, which may contain `maxiter`.

`.makeCC` returns a list containing the check specification (action, tolerance, and optionally relative tolerance).

### See Also

[convergence](#)

### Examples

```
str(lmerControl())
str(glmerControl())
## Not run:
## fit with default "bobyqa" algorithm ...
fm0 <- lmer(Reaction ~ Days + ( 1 | Subject), sleepstudy)
fm1 <- lmer(Reaction ~ Days + (Days | Subject), sleepstudy)
## or with "Nelder-Mead" (the previous default) ...
fm1_bobyqa <- update(fm1, control = lmerControl(optimizer="Nelder-Mead"))
## or with the nlminb function used in older (<1.0) versions of lme4;
## this will usually replicate older results
require(optimx)
fm1_nlminb <- update(fm1,
                    control = lmerControl(optimizer= "optimx",
```

```

                                optCtrl = list(method="nlsminb"))
## The other option here is method="L-BFGS-B".
## Or we can wrap base::optim():
optimwrap <- function(fn,par,lower,upper,control=list(),
  ...) {
  if (is.null(control$method)) stop("must specify method in optCtrl")
  method <- control$method
  control$method <- NULL
  ## "Brent" requires finite upper values (lower bound will always
  ## be zero in this case)
  if (method=="Brent") upper <- pmin(1e4,upper)
  res <- optim(par=par, fn=fn, lower=lower,upper=upper,
    control=control,method=method,...)
  with(res, list(par = par,
    fval = value,
    feval= counts[1],
    conv = convergence,
    message = message))
}
fm0_brent <- update(fm0,
  control = lmerControl(optimizer = "optimwrap",
    optCtrl = list(method="Brent")))
## You can also use functions from the nloptr package.
if (require(nloptr)) {
  defaultControl <- list(algorithm="NLOPT_LN_BOBYQA",
    xtol_abs=1e-6,ftol_abs=1e-6,maxeval=1e5)
  nloptwrap <- function(fn,par,lower,upper,control=list(),...) {
    for (n in names(defaultControl))
      if (is.null(control[[n]])) control[[n]] <- defaultControl[[n]]
    res <- nloptr(x0=par,eval_f=fn,lb=lower,ub=upper,opts=control,...)
    with(res, list(par = solution,
      fval = objective,
      feval= iterations,
      conv = if (status>0) 0 else status,
      message = message))
  }
  fm1_nloptr <- update(fm1, control=lmerControl(optimizer="nloptwrap"))
  fm1_nloptr_NM <- update(fm1, control=lmerControl(optimizer="nloptwrap",
    optCtrl=list(algorithm="NLOPT_LN_NELDERMEAD")))
}
## other algorithm options include NLOPT_LN_COBYLA, NLOPT_LN_SBPLX

## End(Not run)

```

---

lmList

*Fit List of lm Objects with a Common Model*


---

### Description

Fit a list of `lm` objects with a common model for different subgroups of the data.



**Usage**

```
lmList(formula, data, family, subset, weights, na.action,
        offset, pool = TRUE, ...)
```

**Arguments**

formula	a linear <a href="#">formula</a> object of the form $y \sim x_1 + \dots + x_n \mid g$ . In the formula object, $y$ represents the response, $x_1, \dots, x_n$ the covariates, and $g$ the grouping factor specifying the partitioning of the data according to which different <code>lm</code> fits should be performed.
family	an optional family specification for a generalized linear model.
pool	logical scalar, should the variance estimate pool the residual sums of squares
...	additional, optional arguments to be passed to the model function or family evaluation.
data	an optional data frame containing the variables named in <code>formula</code> . By default the variables are taken from the environment from which <code>lmer</code> is called. See <a href="#">Details</a> .
subset	an optional expression indicating the subset of the rows of data that should be used in the fit. This can be a logical vector, or a numeric vector indicating which observation numbers are to be included, or a character vector of the row names to be included. All observations are included by default.
weights	an optional vector of ‘prior weights’ to be used in the fitting process. Should be <code>NULL</code> or a numeric vector.
na.action	a function that indicates what should happen when the data contain NAs. The default action ( <code>na.omit</code> , inherited from the ‘factory fresh’ value of <code>getOption("na.action")</code> ) strips any observations with any missing values in any variables.
offset	this can be used to specify an <i>a priori</i> known component to be included in the linear predictor during fitting. This should be <code>NULL</code> or a numeric vector of length equal to the number of cases. One or more <a href="#">offset</a> terms can be included in the formula instead or as well, and if more than one is specified their sum is used. See <a href="#">model.offset</a> .

**Details**

- While `data` is optional, the package authors *strongly* recommend its use, especially when later applying methods such as `update` and `drop1` to the fitted model (*such methods are not guaranteed to work properly if data is omitted*). If `data` is omitted, variables will be taken from the environment of `formula` (if specified as a formula) or from the parent frame (if specified as a character vector).

**Value**

an object of [class `lmList4`](#) (see there, notably for the [methods](#) defined).

**See Also**

[lmList4](#)

### Examples

```
fm.plm <- lmList(Reaction ~ Days | Subject, sleepstudy)
coef(fm.plm)
fm.2 <- update(fm.plm, pool = FALSE)
## coefficients are the same, "pooled or unpooled":
stopifnot( all.equal(coef(fm.2), coef(fm.plm)) )

(ci <- confint(fm.plm)) # print and rather *see* :
plot(ci)                # how widely they vary for the individuals
```

---

lmList4-class

*Class "lmList4" of 'lm' Objects on Common Model*


---

### Description

Class "lmList4" is an S4 class with basically a [list](#) of objects of class [lm](#) with a common model (but different data); see [lmList\(\)](#) which returns these.

Package [nlme](#)'s [lmList\(\)](#) returns objects of S3 class "lmList" and provides methods for them, on which our methods partly build.

### Objects from the Class

Objects can be created by calls of the form `new("lmList4", ...)` or, more commonly, by a call to [lmList\(\)](#).

### Methods

A dozen [methods](#) are provided. Currently, S4 methods for [show](#), coercion ([as\(.,.\)](#)) and others inherited via "list", and S3 methods for [coef](#), [confint](#), [fitted](#), [fixef](#), [formula](#), [logLik](#), [pairs](#), [plot](#), [predict](#), [print](#), [qqnorm](#), [ranef](#), [residuals](#), [sigma](#), [summary](#), and [update](#).

**sigma(object)** returns the standard deviation  $\hat{\sigma}$  (of the errors in the linear models), assuming a *common* variance  $\sigma^2$  by pooling (even when `pool = FALSE` was used in the fit).

### See Also

[lmList](#)

### Examples

```
if(getRversion() >= "3.2.0") {
  (mm <- methods(class = "lmList4"))
  ## The S3 ("not S4") ones :
  mm[!attr(mm,"info")["isS4"]]
}
## For more examples:  example(lmList)  i.e., ?lmList
```

---

`lmResp`*Generator objects for the response classes*

---

**Description**

The generator objects for the `lmResp`, `lmerResp`, `glmResp` and `nlsResp` reference classes. Such objects are primarily used through their new methods.

**Usage**

```
lmResp(...)
```

**Arguments**

... List of arguments (see Note).

**Methods**

`new(y=y)`: Create a new `lmResp` or `lmerResp` object.

`new(family=family, y=y)`: Create a new `glmResp` object.

`new(y=y, nlmod=nlmod, nlenv=nlenv, pnames=pnames, gam=gam)`: Create a new `nlsResp` object.

**Note**

Arguments to the new methods must be named arguments.

- `y` the numeric response vector
- `family` a `family` object
- `nlmod` the nonlinear model function
- `nlenv` an environment holding data objects for evaluation of `nlmod`
- `pnames` a character vector of parameter names
- `gam` a numeric vector - the initial linear predictor

**See Also**

`lmResp`, `lmerResp`, `glmResp`, `nlsResp`

---

lmResp-class	<i>Reference Classes for Response Modules,</i> "(lm glm nls lmer)Resp"
--------------	---

---

## Description

Reference classes for response modules, including linear models, "lmResp", generalized linear models, "glmResp", nonlinear models, "nlsResp" and linear mixed-effects models, "lmerResp". Each reference class is associated with a C++ class of the same name. As is customary, the generator object for each class has the same name as the class.

## Extends

All reference classes extend and inherit methods from "[envRefClass](#)". Furthermore, "glmResp", "nlsResp" and "lmerResp" all extend the "lmResp" class.

## Note

Objects from these reference classes correspond to objects in C++ classes. Methods are invoked on the C++ classes using the external pointer in the ptr field. When saving such an object the external pointer is converted to a null pointer, which is why there are redundant fields containing enough information as R objects to be able to regenerate the C++ object. The convention is that a field whose name begins with an upper-case letter is an R object and the corresponding field whose name begins with the lower-case letter is a method. Access to the external pointer should be through the method, not through the field.

## See Also

[lmer](#), [glm](#), [nlmer](#), [merMod](#).

## Examples

```
showClass("lmResp")
str(lmResp$new(y=1:4))
showClass("glmResp")
str(glmResp$new(family=poisson(), y=1:4))
showClass("nlsResp")
showClass("lmerResp")
str(lmerResp$new(y=1:4))
```

---

merMod-class	<i>Class "merMod" of Fitted Mixed-Effect Models</i>
--------------	---

---

## Description

A mixed-effects model is represented as a `merPredD` object and a response module of a class that inherits from class `lmResp`. A model with a `lmerResp` response has class `lmerMod`; a `glmResp` response has class `glmerMod`; and a `nlsResp` response has class `nlmerMod`.

## Usage

```
## S3 method for class 'merMod'
anova(object, ..., refit = TRUE, model.names=NULL)
## S3 method for class 'merMod'
coef(object, ...)
## S3 method for class 'merMod'
deviance(object, REML = NULL, ...)
REMLcrit(object)
## S3 method for class 'merMod'
extractAIC(fit, scale = 0, k = 2, ...)
## S3 method for class 'merMod'
family(object, ...)
## S3 method for class 'merMod'
formula(x, fixed.only = FALSE, random.only = FALSE, ...)
## S3 method for class 'merMod'
fitted(object, ...)
## S3 method for class 'merMod'
logLik(object, REML = NULL, ...)
## S3 method for class 'merMod'
nobs(object, ...)
## S3 method for class 'merMod'
ngrps(object, ...)
## S3 method for class 'merMod'
terms(x, fixed.only = TRUE, random.only = FALSE, ...)
## S3 method for class 'merMod'
vcov(object, correlation = TRUE, sigm = sigma(object),
      use.hessian = NULL, ...)
## S3 method for class 'merMod'
model.frame(formula, fixed.only = FALSE, ...)
## S3 method for class 'merMod'
model.matrix(object, type = c("fixed", "random", "randomListRaw"), ...)
## S3 method for class 'merMod'
print(x, digits = max(3, getOption("digits") - 3),
      correlation = NULL, symbolic.cor = FALSE,
      signif.stars = getOption("show.signif.stars"), ranef.comp = "Std.Dev.", ...)

## S3 method for class 'merMod'
```

```

summary(object, correlation = , use.hessian = NULL, ...)
## S3 method for class 'summary.merMod'
print(x, digits = max(3, getOption("digits") - 3),
      correlation = NULL, symbolic.cor = FALSE,
      signif.stars = getOption("show.signif.stars"),
      ranef.comp = c("Variance", "Std.Dev."), show.resids = TRUE, ...)
## S3 method for class 'merMod'
update(object, formula., ..., evaluate = TRUE)
## S3 method for class 'merMod'
weights(object, type = c("prior", "working"), ...)

```

### Arguments

<code>object</code>	an R object of class <code>merMod</code> , i.e., as resulting from <code>lmer()</code> , or <code>glmer()</code> , etc.
<code>x</code>	an R object of class <code>merMod</code> or <code>summary.merMod</code> , respectively, the latter resulting from <code>summary(&lt;merMod&gt;)</code> .
<code>fit</code>	an R object of class <code>merMod</code> .
<code>formula</code>	in the case of <code>model.frame</code> , a <code>merMod</code> object.
<code>refit</code>	logical indicating if objects of class <code>lmerMod</code> should be refitted with ML before comparing models. The default is <code>TRUE</code> to prevent the common mistake of inappropriately comparing REML-fitted models with different fixed effects, whose likelihoods are not directly comparable.
<code>model.names</code>	character vectors of model names to be used in the anova table.
<code>scale</code>	Not currently used (see <code>extractAIC</code> ).
<code>k</code>	see <code>extractAIC</code> .
<code>REML</code>	Logical. If <code>TRUE</code> , return the restricted log-likelihood rather than the log-likelihood. If <code>NULL</code> (the default), set <code>REML</code> to <code>isREML(object)</code> (see <code>isREML</code> ).
<code>fixed.only</code>	logical indicating if only the fixed effects components (terms or formula elements) are sought. If <code>false</code> , all components, including random ones, are returned.
<code>random.only</code>	complement of <code>fixed.only</code> ; indicates whether random components only are sought. (Trying to specify <code>fixed.only</code> and <code>random.only</code> at the same time will produce an error.)
<code>correlation</code>	(logical) for <code>vcov</code> , indicates whether the correlation matrix as well as the variance-covariance matrix is desired; for <code>summary.merMod</code> , indicates whether the correlation matrix should be computed and stored along with the covariance; for <code>print.summary.merMod</code> , indicates whether the correlation matrix of the fixed-effects parameters should be printed. In the latter case, when <code>NULL</code> (the default), the correlation matrix is printed when it has been computed by <code>summary(.)</code> , and when $p \leq 20$ .
<code>use.hessian</code>	(logical) indicates whether to use the finite-difference Hessian of the deviance function to compute standard errors of the fixed effects, rather estimating based on internal information about the inverse of the model matrix (see <code>getME(. , "RX")</code> ). The default is to use the Hessian whenever the fixed effect parameters are arguments to the deviance function (i.e. for GLMMs with $nAGQ > 0$ ), and to use

	<code>getME(. , "RX")</code> whenever the fixed effect parameters are profiled out (i.e. for GLMMs with <code>nAGQ==0</code> or LMMs).
	<code>use.hessian=FALSE</code> is backward-compatible with older versions of lme4, but may give less accurate SE estimates when the estimates of the fixed-effect (see <code>getME(. , "beta")</code> ) and random-effect (see <code>getME(. , "theta")</code> ) parameters are correlated.
<code>sigm</code>	the residual standard error; by default <code>sigma(object)</code> .
<code>digits</code>	number of significant digits for printing
<code>symbolic.cor</code>	should a symbolic encoding of the fixed-effects correlation matrix be printed? If so, the <code>symnum</code> function is used.
<code>signif.stars</code>	(logical) should significance stars be used?
<code>ranef.comp</code>	character vector of length one or two, indicating if random-effects parameters should be reported on the variance and/or standard deviation scale.
<code>show.resids</code>	should the quantiles of the scaled residuals be printed?
<code>formula.</code>	see <code>update.formula</code> .
<code>evaluate</code>	see <code>update</code> .
<code>type</code>	For weights, type of weights to be returned; either "prior" for the initially supplied weights or "working" for the weights at the final iteration of the penalized iteratively reweighted least squares algorithm. For <code>model.matrix</code> , type of model matrix to return (one of fixed giving the fixed effects model matrix, random giving the random effects model matrix, or <code>randomListRaw</code> giving a list of the raw random effects model matrices associated with each random effects term).
<code>...</code>	potentially further arguments passed from other methods.

### Objects from the Class

Objects of class `merMod` are created by calls to `lmer`, `glmer` or `nlmer`.

### S3 methods

The following S3 methods with arguments given above exist (this list is currently not complete):

- `anova`: returns the sequential decomposition of the contributions of fixed-effects terms or, for multiple arguments, model comparison statistics. For objects of class `lmerMod` the default behavior is to refit the models with LM if fitted with `REML = TRUE`, this can be controlled via the `refit` argument. See also `anova`.
- `coef`: Computes the sum of the random and fixed effects coefficients for each explanatory variable for each level of each grouping factor.
- `extractAIC`: Computes the (generalized) Akaike An Information Criterion. If `isREML(fit)`, then `fit` is refitted using maximum likelihood.
- `family`: `family` of fitted GLMM. (*Warning*: this accessor may not work properly with customized families/link functions.)
- `fitted`: Fitted values, given the conditional modes of the random effects. For more flexible access to fitted values, use `predict.merMod`.

`logLik`: Log-likelihood at the fitted value of the parameters. Note that for GLMMs, the returned value is only proportional to the log probability density (or distribution) of the response variable. See [logLik](#).

`model.frame`: returns the frame slot of [merMod](#).

`model.matrix`: returns the fixed effects model matrix.

`nobs, ngrps`: Number of observations and vector of the numbers of levels in each grouping factor. See [ngrps](#).

`summary`: Computes and returns a list of summary statistics of the fitted model, the amount of output can be controlled via the `print` method, see also [summary](#).

`print.summary`: Controls the output for the summary method.

`vcov`: Calculate variance-covariance matrix of the *fixed* effect terms, see also [vcov](#).

`update`: See [update](#).

### Deviance and log-likelihood of GLMMs

One must be careful when defining the deviance of a GLM. For example, should the deviance be defined as minus twice the log-likelihood or does it involve subtracting the deviance for a saturated model? To distinguish these two possibilities we refer to absolute deviance (minus twice the log-likelihood) and relative deviance (relative to a saturated model, e.g. Section 2.3.1 in McCullagh and Nelder 1989). With GLMMs however, there is an additional complication involving the distinction between the likelihood and the conditional likelihood. The latter is the likelihood obtained by conditioning on the estimates of the conditional modes of the spherical random effects coefficients, whereas the likelihood itself (i.e. the unconditional likelihood) involves integrating out these coefficients. The following table summarizes how to extract the various types of deviance for a `glmerMod` object:

	conditional	unconditional
relative	<code>deviance(object)</code>	NA in <code>lme4</code>
absolute	<code>object@resp\$aic()</code>	<code>-2*logLik(object)</code>

This table requires two caveats:

- If the link function involves a scale parameter (e.g. Gamma) then `object@resp$aic() - 2 * getME(object, "deviance")` is required for the absolute-conditional case.
- If adaptive Gauss-Hermite quadrature is used, then `logLik(object)` is currently only proportional to the absolute-unconditional log-likelihood.

For more information about this topic see the `misc/logLikGLMM` directory in the package source.

### Slots

`resp`: A reference class object for an **lme4** response module ([lmResp-class](#)).

`Gp`: See [getME](#).

`call`: The matched call.

`frame`: The model frame containing all of the variables required to parse the model formula.



flist: See [getME](#).  
 cnms: See [getME](#).  
 lower: See [getME](#).  
 theta: Covariance parameter vector.  
 beta: Fixed effects coefficients.  
 u: Conditional model of spherical random effects coefficients.  
 devcomp: See [getME](#).  
 pp: A reference class object for an **lme4** predictor module ([merPredD-class](#)).  
 optinfo: List containing information about the nonlinear optimization.

### See Also

[lmer](#), [glmer](#), [nlmer](#), [merPredD](#), [lmerResp](#), [glmResp](#), [nlsResp](#)

Other methods for merMod objects documented elsewhere include: [fortify.merMod](#), [drop1.merMod](#), [isLMM.merMod](#), [isGLMM.merMod](#), [isNLMM.merMod](#), [isREML.merMod](#), [plot.merMod](#), [predict.merMod](#), [profile.merMod](#), [ranef.merMod](#), [refit.merMod](#), [refitML.merMod](#), [residuals.merMod](#), [sigma.merMod](#), [simulate.merMod](#), [summary.merMod](#).

### Examples

```

showClass("merMod")
methods(class="merMod")## over 30 (S3) methods available

## -> example(lmer) for an example of vcov.merMod()

```

---

merPredD

*Generator object for the merPredD class*

---

### Description

The generator object for the [merPredD](#) reference class. Such an object is primarily used through its new method.

### Usage

```
merPredD(...)
```

### Arguments

... List of arguments (see Note).

**Note**

merPredD(...) is a short form of new("merPredD", ...) to create a new [merPredD](#) object and the ... must be named arguments, (X, Zt, Lambdat, Lind, theta,n):

**X:** dense model matrix for the fixed-effects parameters, to be stored in the X field.

**Zt:** transpose of the sparse model matrix for the random effects. It is stored in the Zt field.

**Lambdat:** transpose of the sparse lower triangular relative variance factor (stored in the Lambdat field).

**Lind:** integer vector of the same length as the x slot in the Lambdat field. Its elements should be in the range 1 to the length of the theta field.

**theta:** numeric vector of variance component parameters (stored in the theta field).

**n:** sample size, usually nrow(X).

**See Also**

The class definition, [merPredD](#), also for examples.

---

merPredD-class	<i>Class "merPredD" - a Dense Predictor Reference Class</i>
----------------	---

---

**Description**

A reference class (see mother class definition "[envRefClass](#)" for a mixed-effects model predictor module with a dense model matrix for the fixed-effects parameters. The reference class is associated with a C++ class of the same name. As is customary, the generator object, [merPredD](#), for the class has the same name as the class.

**Note**

Objects from this reference class correspond to objects in a C++ class. Methods are invoked on the C++ class object using the external pointer in the Ptr field. When saving such an object the external pointer is converted to a null pointer, which is why there are redundant fields containing enough information as R objects to be able to regenerate the C++ object. The convention is that a field whose name begins with an upper-case letter is an R object and the corresponding field, whose name begins with the lower-case letter is a method. References to the external pointer should be through the method, not directly through the Ptr field.

**See Also**

[lmer](#), [glmer](#), [nlmer](#), [merPredD](#), [merMod](#).

**Examples**

```
showClass("merPredD")
pp <- slot(lmer(Yield ~ 1|Batch, Dyestuff), "pp")
stopifnot(is(pp, "merPredD"))
str(pp) # an overview of all fields and methods' names.
```

---

mkdevfun	<i>Create Deviance Evaluation Function from Predictor and Response Module</i>
----------	---

---

### Description

From a [merMod](#) object create an R function that takes a single argument, which is the new parameter value, and returns the deviance.

### Usage

```
mkdevfun(rho, nAGQ = 1L, maxit = 100, verbose = 0, control = list())
```

### Arguments

rho	an environment containing pp, a prediction module, typically of class <a href="#">merPredD</a> and resp, a response module, e.g., of class <a href="#">lmerResp</a> .
nAGQ	scalar integer - the number of adaptive Gauss-Hermite quadrature points. A value of 0 indicates that both the fixed-effects parameters and the random effects are optimized by the iteratively reweighted least squares algorithm.
maxit	scalar integer, currently only for GLMMs: the maximal number of Pwrss update iterations.
verbose	scalar logical: print verbose output?
control	list of control parameters, a subset of those specified by <a href="#">lmerControl</a> (tolPwrss and compDev for GLMMs, tolPwrss for NLMMs)

### Details

The function returned by `mkdevfun` evaluates the deviance of the model represented by the predictor module, pp, and the response module, resp.

For [lmer](#) model objects the argument of the resulting function is the variance component parameter, theta, with lower bound. For [glmer](#) or [nlmer](#) model objects with `nAGQ = 0` the argument is also theta. However, when `nAGQ > 0`, the argument is `c(theta, beta)`.

### Value

A [function](#) of one numeric argument.

### See Also

[lmer](#), [glmer](#) and [nlmer](#)

### Examples

```
(dd <- lmer(Yield ~ 1|Batch, Dyestuff, devFunOnly=TRUE))
dd(0.8)
minqa::bobyqa(1, dd, 0)
```

---

mkMerMod *Create a 'merMod' Object*

---

### Description

Create an object of (a subclass of) class [merMod](#) from the environment of the objective function and the value returned by the optimizer.

### Usage

```
mkMerMod(rho, opt, reTrms, fr, mc, lme4conv = NULL)
```

### Arguments

rho	the environment of the objective function
opt	the optimization result returned by the optimizer (a <a href="#">list</a> : see <a href="#">lmerControl</a> for required elements)
reTrms	random effects structure from the calling function (see <a href="#">mkReTrms</a> for required elements)
fr	model frame (see <a href="#">model.frame</a> )
mc	matched call from the calling function
lme4conv	lme4-specific convergence information (results of <a href="#">checkConv</a> )

### Value

an object from a class that inherits from [merMod](#).

---

mkRespMod *Create an lmerResp, glmResp or nlsResp instance*

---

### Description

Create an [lmerResp](#), [glmResp](#) or [nlsResp](#) instance

### Usage

```
mkRespMod(fr, REML = NULL, family = NULL, nlenv = NULL,
           nlmod = NULL, ...)
```

**Arguments**

fr	a model frame
REML	logical scalar, value of REML for an lmerResp instance
family	the optional glm family (glmResp only)
n1env	the nonlinear model evaluation environment (nlsResp only)
n1mod	the nonlinear model function (nlsResp only)
...	where to look for response information if fr is missing. Can contain a model response, y, offset, offset, and weights, weights.

**Value**

an lmerResp or glmResp or nlsResp instance

**See Also**

Other utilities: [findbars](#), [mkReTrms](#), [nlformula](#), [nobars](#), [subbars](#)

---

mkReTrms

---

*Make Random Effect Terms: Create Z, Lambda, Lind, etc.*


---

**Description**

From the result of [findbars](#) applied to a model formula and the evaluation frame fr, create the model matrix Zt, etc, associated with the random-effects terms.

**Usage**

```
mkReTrms(bars, fr, drop.unused.levels=TRUE)
```

**Arguments**

bars	a list of parsed random-effects terms
fr	a model frame in which to evaluate these terms
drop.unused.levels	(logical) drop unused factor levels? (experimental)

**Value**

a [list](#) with components

Zt	transpose of the sparse model matrix for the random effects
theta	initial values of the covariance parameters
Lind	an integer vector of indices determining the mapping of the elements of the theta vector to the "x" slot of Lambdat
Gp	

lower	lower bounds on the covariance parameters
Lambdat	transpose of the sparse relative covariance factor
flist	list of grouping factors used in the random-effects terms
cnms	a list of column names of the random effects according to the grouping factors
Ztlist	list of components of the transpose of the random-effects model matrix, separated by random-effects term

### See Also

Other utilities: [findbars](#), [mkRespMod](#), [nlformula](#), [nobars](#), [subbars](#). [getME](#) can retrieve these components from a fitted model, although their values and/or forms may be slightly different in the final fitted model from their original values as returned from [mkReTrms](#).

### Examples

```
data("Pixel", package="nlme")
mform <- pixel ~ day + I(day^2) + (day | Dog) + (1 | Side/Dog)
(bar.f <- findbars(mform)) # list with 3 terms
mf <- model.frame(subbars(mform), data=Pixel)
rt <- mkReTrms(bar.f, mf)
names(rt)
```

---

mkSimulateTemplate      *Make templates suitable for guiding mixed model simulations*

---

### Description

Make data and parameter templates suitable for guiding mixed model simulations, by specifying a model formula and other information (EXPERIMENTAL). Most useful for simulating balanced designs and for getting started on unbalanced simulations.

### Usage

```
mkParsTemplate(formula, data)
mkDataTemplate(formula, data, nGrps = 2, nPerGrp = 1, rfunc = NULL, ...)
```

### Arguments

formula	A mixed model formula (see <a href="#">lmer</a> ).
data	A data frame containing the names in formula.
nGrps	Number of levels of a grouping factor.
nPerGrp	Number of observations per level.
rfunc	Function for generating covariate data (e.g. <a href="#">rnorm</a> ).
...	Additional parameters for rfunc.

### See Also

These functions are designed to be used with [simulate.merMod](#).

---

mkVarCorr	<i>Make Variance and Correlation Matrices from theta</i>
-----------	--

---

**Description**

Make variance and correlation matrices from theta

**Usage**

```
mkVarCorr(sc, cnms, nc, theta, nms)
```

**Arguments**

sc	scale factor (residual standard deviation).
cnms	component names.
nc	numeric vector: number of terms in each RE component.
theta	theta vector (lower-triangle of Cholesky factors).
nms	component names (FIXME: nms/cnms redundant: nms=names(cnms)?)

**Value**

A [matrix](#)

**See Also**

[VarCorr](#)

---

modular	<i>Modular Functions for Mixed Model Fits</i>
---------	---

---

**Description**

Modular functions for mixed model fits

**Usage**

```
lFormula(formula, data = NULL, REML = TRUE, subset,
          weights, na.action, offset, contrasts = NULL,
          control = lmerControl(), ...)

mkLmerDevfun(fr, X, reTrms, REML = TRUE, start = NULL,
            verbose = 0, control = lmerControl(), ...)

optimizeLmer(devfun,
             optimizer = formals(lmerControl)$optimizer,
```

```

restart_edge = formals(lmerControl)$restart_edge,
boundary.tol = formals(lmerControl)$boundary.tol,
start = NULL, verbose = 0L,
control = list(), ...)

glFormula(formula, data = NULL, family = gaussian,
  subset, weights, na.action, offset, contrasts = NULL,
  mustart, etastart, control = glmerControl(), ...)

mkGlmerDevfun(fr, X, reTrms, family, nAGQ = 1L,
  verbose = 0L, maxit = 100L, control = glmerControl(), ...)

optimizeGlmer(devfun, optimizer = "bobyqa",
  restart_edge = FALSE,
  boundary.tol = formals(glmerControl)$boundary.tol,
  verbose = 0L, control = list(),
  nAGQ = 1L, stage = 1, start = NULL, ...)

updateGlmerDevfun(devfun, reTrms, nAGQ = 1L)

```

### Arguments

formula	a two-sided linear formula object describing both the fixed-effects and random-effects parts of the model, with the response on the left of a <code>~</code> operator and the terms, separated by <code>+</code> operators, on the right. Random-effects terms are distinguished by vertical bars ( <code> </code> ) separating expressions for design matrices from grouping factors.
data	an optional data frame containing the variables named in formula. By default the variables are taken from the environment from which <code>lmer</code> is called. While data is optional, the package authors <i>strongly</i> recommend its use, especially when later applying methods such as <code>update</code> and <code>drop1</code> to the fitted model ( <i>such methods are not guaranteed to work properly if data is omitted</i> ). If data is omitted, variables will be taken from the environment of formula (if specified as a formula) or from the parent frame (if specified as a character vector).
REML	(logical) indicating to fit <b>restricted</b> maximum likelihood model.
subset	an optional expression indicating the subset of the rows of data that should be used in the fit. This can be a logical vector, or a numeric vector indicating which observation numbers are to be included, or a character vector of the row names to be included. All observations are included by default.
weights	an optional vector of ‘prior weights’ to be used in the fitting process. Should be <code>NULL</code> or a numeric vector.
na.action	a function that indicates what should happen when the data contain NAs. The default action ( <code>na.omit</code> , inherited from the ‘factory fresh’ value of <code>getOption("na.action")</code> ) strips any observations with any missing values in any variables.
offset	this can be used to specify an <i>a priori</i> known component to be included in the linear predictor during fitting. This should be <code>NULL</code> or a numeric vector of length equal to the number of cases. One or more <code>offset</code> terms can be included in the



	formula instead or as well, and if more than one is specified their sum is used. See <code>model.offset</code> .
<code>contrasts</code>	an optional <code>list</code> . See the <code>contrasts.arg</code> of <code>model.matrix.default</code> .
<code>control</code>	a list giving <ul style="list-style-type: none"> <li><b>for</b> <code>[g]lFormula</code>: all options for running the model, see <code>lmerControl</code>;</li> <li><b>for</b> <code>mkLmerDevfun</code>, <code>mkGlmrDevfun</code>: options for the inner optimization step;</li> <li><b>for</b> <code>optimizeLmer</code> <b>and</b> <code>optimizeGlmr</code>: control parameters for nonlinear optimizer (typically inherited from the ... argument to <code>lmerControl</code>).</li> </ul>
<code>fr</code>	A model frame containing the variables needed to create an <code>lmerResp</code> or <code>glmrResp</code> instance.
<code>X</code>	fixed-effects design matrix
<code>reTrms</code>	information on random effects structure (see <code>mkReTrms</code> ).
<code>start</code>	starting values (see <code>lmer</code> )
<code>verbose</code>	print output?
<code>maxit</code>	maximal number of Pwrss update iterations.
<code>devfun</code>	a deviance function, as generated by <code>mkLmerDevfun</code>
<code>nAGQ</code>	number of Gauss-Hermite quadrature points
<code>stage</code>	optimization stage (1: <code>nAGQ=0</code> , optimize over theta only; 2: <code>nAGQ</code> possibly <code>&gt;0</code> , optimize over theta and beta)
<code>optimizer</code>	<p>character - name of optimizing function(s). A character vector or list of functions: length 1 for <code>lmer</code> or <code>glmer</code>, possibly length 2 for <code>glmer</code>. The built-in optimizers are "<code>Nelder_Mead</code>" and "<code>bobyqa</code>" (from the <code>minqa</code> package). Any minimizing function that allows box constraints can be used provided that it</p> <ol style="list-style-type: none"> <li>1. takes input parameters <code>fn</code> (function to be optimized), <code>par</code> (starting parameter values), <code>lower</code> (lower bounds) and <code>control</code> (control parameters, passed through from the <code>control</code> argument) and</li> <li>2. returns a list with (at least) elements <code>par</code> (best-fit parameters), <code>fval</code> (best-fit function value), <code>conv</code> (convergence code) and (optionally) <code>message</code> (informational message, or explanation of convergence failure).</li> </ol> <p>Special provisions are made for <code>bobyqa</code>, <code>Nelder_Mead</code>, and optimizers wrapped in the <code>optimx</code> package; to use <code>optimx</code> optimizers (including L-BFGS-B from base <code>optim</code> and <code>nlminb</code>), pass the <code>method</code> argument to <code>optim</code> in the <code>control</code> argument.</p> <p>For <code>glmer</code>, if <code>length(optimizer)==2</code>, the first element will be used for the preliminary (random effects parameters only) optimization, while the second will be used for the final (random effects plus fixed effect parameters) phase. See <code>modular</code> for more information on these two phases.</p>
<code>restart_edge</code>	see <code>lmerControl</code>
<code>boundary.tol</code>	see <code>lmerControl</code>
<code>family</code>	a GLM family; see <code>glm</code> and <code>family</code> .
<code>mustart</code>	optional starting values on the scale of the conditional mean; see <code>glm</code> for details.

`etastart` optional starting values on the scale of the unbounded predictor; see [glm](#) for details.

`...` other potential arguments; for `optimizeLmer` and `optimizeGlmmer`, these are passed to internal function `optwrap`, which has relevant parameters `calc.derivs` and `use.last.params` (see [lmerControl](#)).

## Details

These functions make up the internal components of an `[gn]lmer` fit.

- `[g]lFormula` takes the arguments that would normally be passed to `[g]lmer`, checking for errors and processing the formula and data input to create a list of objects required to fit a mixed model.
- `mk(Gl|L)merDevfun` takes the output of the previous step (minus the formula component) and creates a deviance function
- `optimize(Gl|L)mer` takes a deviance function and optimizes over `theta` (or over `theta` and `beta`, if `stage` is set to 2 for `optimizeGlmmer`)
- `updateGlmmerDevfun` takes the first stage of a GLMM optimization (with `nAGQ=0`, optimizing over `theta` only) and produces a second-stage deviance function
- `mkMerMod` takes the *environment* of a deviance function, the results of an optimization, a list of random-effect terms, a model frame, and a model all and produces a `[g]lmerMod` object.

## Value

`lFormula` and `glFormula` return a list containing components:

**fr** model frame

**X** fixed-effect design matrix

**reTrms** list containing information on random effects structure: result of [mkReTrms](#)

**REML** (`lFormula` only): logical indicating if restricted maximum likelihood was used (Copy of argument.)

`mkLmerDevfun` and `mkGlmmerDevfun` return a function to calculate deviance (or restricted deviance) as a function of the `theta` (random-effect) parameters. `updateGlmmerDevfun` returns a function to calculate the deviance as a function of a concatenation of `theta` and `beta` (fixed-effect) parameters. These deviance functions have an environment containing objects required for their evaluation. CAUTION: The *environment* of functions returned by `mk(Gl|L)merDevfun` contains reference class objects (see [ReferenceClasses](#), [merPredD-class](#), [lmResp-class](#)), which behave in ways that may surprise many users. For example, if the output of `mk(Gl|L)merDevfun` is naively copied, then modifications to the original will also appear in the copy (and vice versa). To avoid this behavior one must make a deep copy (see [ReferenceClasses](#) for details).

`optimizeLmer` and `optimizeGlmmer` return the results of an optimization.

**Examples**

```

### Fitting a linear mixed model in 4 modularized steps

## 1. Parse the data and formula:
lmod <- lFormula(Reaction ~ Days + (Days|Subject), sleepstudy)
names(lmod)
## 2. Create the deviance function to be optimized:
(devfun <- do.call(mkLmerDevfun, lmod))
ls(environment(devfun)) # the environment of 'devfun' contains objects
                        # required for its evaluation
## 3. Optimize the deviance function:
opt <- optimizeLmer(devfun)
opt[1:3]
## 4. Package up the results:
mkMerMod(environment(devfun), opt, lmod$reTrms, fr = lmod$fr)

### Same model in one line
lmer(Reaction ~ Days + (Days|Subject), sleepstudy)

### Fitting a generalized linear mixed model in six modularized steps

## 1. Parse the data and formula:
glmod <- glFormula(cbind(incidence, size - incidence) ~ period + (1 | herd),
data = cbpp, family = binomial)
names(glmod)
## 2. Create the deviance function for optimizing over theta:
(devfun <- do.call(mkGlmrDevfun, glmod))
ls(environment(devfun)) # the environment of devfun contains lots of info
## 3. Optimize over theta using a rough approximation (i.e. nAGQ = 0):
(opt <- optimizeGlmr(devfun))
## 4. Update the deviance function for optimizing over theta and beta:
(devfun <- updateGlmrDevfun(devfun, glmod$reTrms))
## 5. Optimize over theta and beta:
opt <- optimizeGlmr(devfun, stage=2)
opt[1:3]
## 6. Package up the results:
mkMerMod(environment(devfun), opt, glmod$reTrms, fr = glmod$fr)

### Same model in one line
glmer(cbind(incidence, size - incidence) ~ period + (1 | herd),
      data = cbpp, family = binomial)

```

---

NelderMead

*Nelder-Mead Optimization of Parameters, Possibly (Box) Constrained*


---

**Description**

Nelder-Mead optimization of parameters, allowing optimization subject to box constraints (contrary to the default, `method = "Nelder-Mead"`, in R's `optim()`), and using reverse communications.

**Usage**

```
Nelder_Mead(fn, par, lower = rep.int(-Inf, n), upper = rep.int(Inf, n),
            control = list())
```

**Arguments**

**fn** a [function](#) of a single numeric vector argument returning a numeric scalar.

**par** numeric vector of starting values for the parameters.

**lower** numeric vector of lower bounds (elements may be `-Inf`).

**upper** numeric vector of upper bounds (elements may be `Inf`).

**control** a named list of control settings. Possible settings are

- iprint** numeric scalar - frequency of printing evaluation information. Defaults to 0 indicating no printing.
- maxfun** numeric scalar - maximum number of function evaluations allowed (default:10000).
- FtolAbs** numeric scalar - absolute tolerance on change in function values (default: 1e-5)
- FtolRel** numeric scalar - relative tolerance on change in function values (default:1e-15)
- XtolRel** numeric scalar - relative tolerance on change in parameter values (default: 1e-7)
- MinfMax** numeric scalar - maximum value of the minimum (default: `.Machine$double.xmin`)
- xst** numeric vector of initial step sizes to establish the simplex - all elements must be non-zero (default: `rep(0.02,length(par))`)
- xt** numeric vector of tolerances on the parameters (default: `xst*5e-4`)
- verbose** numeric value: 0=no printing, 1=print every 20 evaluations, 2=print every 10 evaluations, 3=print every evaluation. Sets 'iprint', if specified, but does not override it.
- warnOnly** a logical indicating if non-convergence (codes -1,-2,-3) should not [stop](#)(.), but rather only call [warning](#) and return a result which might inspected. Defaults to FALSE, i.e., stop on non-convergence.

**Value**

a [list](#) with components

**fval** numeric scalar - the minimum function value achieved

**par** numeric vector - the value of `x` providing the minimum

**convergence** integer valued scalar, if not 0, an error code:

- 4** `nm_evals`: maximum evaluations reached
- 3** `nm_forced`: ?
- 2** `nm_nofeasible`: cannot generate a feasible simplex
- 1** `nm_x0notfeasible`: initial `x` is not feasible (?)

	<b>0</b>	successful convergence
message		a string specifying the kind of convergence.
control		the <a href="#">list</a> of control settings after substituting for defaults.
feval		the number of function evaluations.

**See Also**

The [NelderMead](#) class definition and generator function.

**Examples**

```
fr <- function(x) { ## Rosenbrock Banana function
  x1 <- x[1]
  x2 <- x[2]
  100 * (x2 - x1 * x1)^2 + (1 - x1)^2
}
p0 <- c(-1.2, 1)

oo <- optim(p0, fr) ## also uses Nelder-Mead by default
o. <- Nelder_Mead(fr, p0)
o.1 <- Nelder_Mead(fr, p0, control=list(verbose=1))# -> some iteration output
stopifnot(identical(o.[1:4], o.1[1:4]),
           all.equal(o.$par, oo$par, tolerance=1e-3))# diff: 0.0003865

o.2 <- Nelder_Mead(fr, p0, control=list(verbose=3, XtolRel=1e-15, FtolAbs= 1e-14))
all.equal(o.2[-5],o.1[-5], tolerance=1e-15)# TRUE, unexpectedly
```

---

NelderMead-class      *Class "NelderMead" of Nelder-Mead optimizers and its Generator*

---

**Description**

Class "NelderMead" is a reference class for a Nelder-Mead simplex optimizer allowing box constraints on the parameters and using reverse communication.

The `NelderMead()` function conveniently generates such objects.

**Usage**

```
NelderMead(...)
```

**Arguments**

...                    Argument list (see Note below).

**Methods**

```
NelderMead$new(lower, upper, xst, x0, xt)
```

Create a new [NelderMead](#) object

**Extends**

All reference classes extend and inherit methods from "[envRefClass](#)".

**Note**

This is the default optimizer for the second stage of [glmer](#) and [nlmer](#) fits. We found that it was more reliable and often faster than more sophisticated optimizers.

Arguments to `NelderMead()` and the [new](#) method must be named arguments:

**lower** numeric vector of lower bounds - elements may be `-Inf`.

**upper** numeric vector of upper bounds - elements may be `Inf`.

**xst** numeric vector of initial step sizes to establish the simplex - all elements must be non-zero.

**x0** numeric vector of starting values for the parameters.

**xt** numeric vector of tolerances on the parameters.

**References**

Based on code in the NLOpt collection.

**See Also**

[Nelder\\_Mead](#), the typical "constructor". Further, [glmer](#), [nlmer](#)

**Examples**

```
showClass("NelderMead")
```

---

ngrps

*Number of Levels of a Factor or a "merMod" Model*


---

**Description**

Returns the number of levels of a [factor](#) or a set of factors, currently e.g., for each of the grouping factors of [lmer\(\)](#), [glmer\(\)](#), etc.

**Usage**

```
ngrps(object, ...)
```

**Arguments**

`object` an R object, see Details.

`...` currently ignored.

**Details**

Currently there are methods for objects of class `merMod`, i.e., the result of `lmer()` etc, and `factor` objects.

**Value**

The number of levels (of a factor) or vector of number of levels for each “grouping factor” of a

**Examples**

```
ngrps(factor(seq(1,10,2)))
ngrps(lmer(Reaction ~ 1|Subject, sleepstudy))

## A named vector if there's more than one grouping factor :
ngrps(lmer(strength ~ (1|batch/cask), Pastes))
## cask:batch      batch
##           30      10

methods(ngrps) # -> "factor" and "merMod"
```

---

nlformula

*Manipulate a Nonlinear Model Formula*


---

**Description**

Check and manipulate the formula for a nonlinear model, such as specified in `nlmer`.

**Usage**

```
nlformula(mc)
```

**Arguments**

`mc` matched call from the calling function, typically `nlmer()`. Should have arguments named

**formula:** a formula of the form `resp ~ nlmod ~ meform` where `resp` is an expression for the response, `nlmod` is the nonlinear model expression and `meform` is the mixed-effects model formula. `resp` can be omitted when, e.g., optimizing a design.

**data:** a data frame in which to evaluate the model function

**start:** either a numeric vector containing initial estimates for the nonlinear model parameters or a list with components

`nlpars:` the initial estimates of the nonlinear model parameters

`theta:` the initial estimates of the variance component parameters

**Details**

The model formula for a nonlinear mixed-effects model is of the form `resp ~ nlmod ~ mixed` where `resp` is an expression (usually just a name) for the response, `nlmod` is the call to the nonlinear model function, and `mixed` is the mixed-effects formula defining the linear predictor for the parameter matrix. If the formula is to be used for optimizing designs, the `resp` part can be omitted.

**Value**

a list with components

"respMod"	a response module of class "nlsResp"
"frame"	the model frame, including a terms attribute
"X"	the fixed-effects model matrix
"reTrms"	the random-effects terms object

**See Also**

Other utilities: [findbars](#), [mkRespMod](#), [mkReTrms](#), [nobars](#), [subbars](#)

---

nlmer

*Fitting Nonlinear Mixed-Effects Models*


---

**Description**

Fit a nonlinear mixed-effects model (NLMM) to data, via maximum likelihood.

**Usage**

```
nlmer(formula, data = NULL, control = nlmerControl(),
      start = NULL, verbose = 0L, nAGQ = 1L, subset, weights, na.action,
      offset, contrasts = NULL, devFunOnly = FALSE, ...)
```

**Arguments**

formula	a three-part “nonlinear mixed model” formula, of the form <code>resp ~ Nonlin(...) ~ fixed + random</code> , where the third part is similar to the RHS formula of, e.g., <a href="#">lmer</a> . Currently, the <code>Nonlin(...)</code> formula part must not only return a numeric vector, but also must have a “gradient” attribute, a <a href="#">matrix</a> . The functions <a href="#">SSbiexp</a> , <a href="#">SSlogis</a> , etc, see <a href="#">selfStart</a> , provide this (and more). Alternatively, you can use <a href="#">deriv()</a> to automatically produce such functions or expressions.
data	an optional data frame containing the variables named in formula. By default the variables are taken from the environment from which <code>lmer</code> is called. While <code>data</code> is optional, the package authors <i>strongly</i> recommend its use, especially when later applying methods such as <a href="#">update</a> and <a href="#">drop1</a> to the fitted model ( <i>such methods are not guaranteed to work properly if data is omitted</i> ). If <code>data</code> is omitted, variables will be taken from the environment of <code>formula</code> (if specified as a formula) or from the parent frame (if specified as a character vector).



control	a list (of correct class, resulting from <code>lmerControl()</code> or <code>glmerControl()</code> respectively) containing control parameters, including the nonlinear optimizer to be used and parameters to be passed through to the nonlinear optimizer, see the <code>*lmerControl</code> documentation for details.
start	starting estimates for the nonlinear model parameters, as a named numeric vector or as a list with components  <b>nlpars</b> required numeric vector of starting values for the nonlinear model parameters <b>theta</b> optional numeric vector of starting values for the covariance parameters
verbose	integer scalar. If $> 0$ verbose output is generated during the optimization of the parameter estimates. If $> 1$ verbose output is generated during the individual PIRLS steps.
nAGQ	integer scalar - the number of points per axis for evaluating the adaptive Gauss-Hermite approximation to the log-likelihood. Defaults to 1, corresponding to the Laplace approximation. Values greater than 1 produce greater accuracy in the evaluation of the log-likelihood at the expense of speed. A value of zero uses a faster but less exact form of parameter estimation for GLMMs by optimizing the random effects and the fixed-effects coefficients in the penalized iteratively reweighted least squares step.
subset	an optional expression indicating the subset of the rows of data that should be used in the fit. This can be a logical vector, or a numeric vector indicating which observation numbers are to be included, or a character vector of the row names to be included. All observations are included by default.
weights	an optional vector of 'prior weights' to be used in the fitting process. Should be NULL or a numeric vector.
na.action	a function that indicates what should happen when the data contain NAs. The default action ( <code>na.omit</code> , inherited from the 'factory fresh' value of <code>getOption("na.action")</code> ) strips any observations with any missing values in any variables.
offset	this can be used to specify an <i>a priori</i> known component to be included in the linear predictor during fitting. This should be NULL or a numeric vector of length equal to the number of cases. One or more <code>offset</code> terms can be included in the formula instead or as well, and if more than one is specified their sum is used. See <code>model.offset</code> .
contrasts	an optional <code>list</code> . See the <code>contrasts.arg</code> of <code>model.matrix.default</code> .
devFunOnly	logical - return only the deviance evaluation function. Note that because the deviance function operates on variables stored in its environment, it may not return <i>exactly</i> the same values on subsequent calls (but the results should always be within machine tolerance).
...	other potential arguments. A method argument was used in earlier versions of the package. Its functionality has been replaced by the <code>nAGQ</code> argument.

## Details

Fit nonlinear mixed-effects models, such as those used in population pharmacokinetics.

**Note**

Adaptive Gauss-Hermite quadrature (nAGQ>1) is not currently implemented for nlmer. Several other methods, such as simulation or prediction with new data, are unimplemented or very lightly tested.

**Examples**

```
## nonlinear mixed models --- 3-part formulas ---
## 1. basic nonlinear fit. Use stats::SSlogis for its
## implementation of the 3-parameter logistic curve.
## "SS" stands for "self-starting logistic", but the
## "self-starting" part is not currently used by nlmer ... 'start' is
## necessary
startvec <- c(Asym = 200, xmid = 725, scal = 350)
(nm1 <- nlmer(circumference ~ SSlogis(age, Asym, xmid, scal) ~ Asym|Tree,
             Orange, start = startvec))
## 2. re-run with "quick and dirty" PIRLS step
(nm1a <- update(nm1, nAGQ = 0L))

## 3. Fit the same model with a user-built function:
## a. Define formula
nform <- ~Asym/(1+exp((xmid-input)/scal))
## b. Use deriv() to construct function:
nfun <- deriv(nform,namevec=c("Asym","xmid","scal"),
             function.arg=c("input","Asym","xmid","scal"))
nm1b <- update(nm1,circumference ~ nfun(age, Asym, xmid, scal) ~ Asym | Tree)

## 4. User-built function without using derivs():
## derivatives could be computed more efficiently
## by pre-computing components, but these are essentially
## the gradients as one would derive them by hand
nfun2 <- function(input, Asym, xmid, scal) {
  value <- Asym/(1+exp((xmid-input)/scal))
  grad <- cbind(Asym=1/(1+exp((xmid-input)/scal)),
               xmid=-Asym/(1+exp((xmid-input)/scal))^2*1/scal*
               exp((xmid-input)/scal),
               scal=-Asym/(1+exp((xmid-input)/scal))^2*
               -(xmid-input)/scal^2*exp((xmid-input)/scal))
  attr(value,"gradient") <- grad
  value
}
stopifnot(all.equal(attr(nfun(2,1,3,4),"gradient"),
                    attr(nfun(2,1,3,4),"gradient"))))
nm1c <- update(nm1,circumference ~ nfun2(age, Asym, xmid, scal) ~ Asym | Tree)
```

**Description**

Wrappers to allow use of alternative optimizers, from NLOpt library or elsewhere, for nonlinear optimization stage

**Usage**

```
nloptwrap(par, fn, lower, upper, control=list(),...)
nlminbwrap(par, fn, lower, upper, control=list(),...)
```

**Arguments**

par	starting parameter vector
fn	objective function
lower	vector of lower bounds
upper	vector of upper bounds
control	list of control parameters
...	additional arguments to be passed to objective function

**Details**

Using alternative optimizers is an important trouble-shooting tool for mixed models. These wrappers provide convenient access to the optimizers provided by Steven Johnson's NLOpt library (via the `nloptr` R package), and to the `nlminb` optimizer from base R. (`nlminb` is also available via the `optimx` package; this wrapper provides access to `nlminb` without the need to install/link the package, and without the additional post-fitting checks that are implemented by `optimx` (see examples below).

One important difference between the `nloptr`-provided implementation of BOBYQA and the `minqa`-provided version accessible via `optimizer="bobyqa"` is that it provides simpler access to optimization tolerances. `minqa:bobyqa` provides only the `rhoend` parameter ("[t]he smallest value of the trust region radius that is allowed"), while `nloptr` provides a more standard set of tolerances for relative or absolute change in the objective function or the parameter values (`ftol_rel`, `ftol_abs`, `xtol_rel`, `xtol_abs`).

**Value**

par	estimated parameters
fval	objective function value at minimum
feval	number of function evaluations
conv	convergence code (0 if no error)
message	convergence message

**Author(s)**

Gabor Grothendieck (`nlminbwrap`)

**Examples**

```

environment(nloptwrap)$defaultControl
library(lme4)
fm1 <- lmer(Reaction~Days+(Days|Subject),sleepstudy)
## BOBYQA (default)
fm1_nloptr <- update(fm1,control=lmerControl(optimizer="nloptwrap"))
## Nelder-Mead
fm1_nloptr_NM <- update(fm1,control=lmerControl(optimizer="nloptwrap",
                                             optCtrl=list(algorithm="NLOPT_LN_NELDERMEAD")))
## other nlopt algorithm options include NLOPT_LN_COBYLA, NLOPT_LN_SBPLX
fm1_nlminb <- update(fm1,control=lmerControl(optimizer="nlminbwrap"))
if (require(optimx)) {
  fm1_nlminb2 <- update(fm1,control=lmerControl(optimizer="optimx",
                                             optCtrl=list(method="nlminb",kkt=FALSE)))
}

```

---

nobars

*Omit terms separated by vertical bars in a formula*


---

**Description**

Remove the random-effects terms from a mixed-effects formula, thereby producing the fixed-effects formula.

**Usage**

```
nobars(term)
```

**Arguments**

term                    the right-hand side of a mixed-model formula

**Value**

the fixed-effects part of the formula

**Note**

This function is called recursively on individual terms in the model, which is why the argument is called `term` and not a name like `form`, indicating a formula.

**See Also**

[formula](#), [model.frame](#), [model.matrix](#).

Other utilities: [findbars](#), [mkRespMod](#), [mkReTrms](#), [nlformula](#), [subbars](#)

**Examples**

```
nobars(Reaction ~ Days + (Days|Subject)) ## => Reaction ~ Days
```

---

 Pastes

*Paste strength by batch and cask*


---

### Description

Strength of a chemical paste product; its quality depending on the delivery batch, and the cask within the delivery.

### Format

A data frame with 60 observations on the following 4 variables.

strength paste strength.

batch delivery batch from which the sample was sample. A factor with 10 levels: 'A' to 'J'.

cask cask within the delivery batch from which the sample was chosen. A factor with 3 levels: 'a' to 'c'.

sample the sample of paste whose strength was assayed, two assays per sample. A factor with 30 levels: 'A:a' to 'J:c'.

### Details

The data are described in Davies and Goldsmith (1972) as coming from “ deliveries of a chemical paste product contained in casks where, in addition to sampling and testing errors, there are variations in quality between deliveries ... As a routine, three casks selected at random from each delivery were sampled and the samples were kept for reference. ... Ten of the delivery batches were sampled at random and two analytical tests carried out on each of the 30 samples”.

### Source

O.L. Davies and P.L. Goldsmith (eds), *Statistical Methods in Research and Production*, 4th ed., Oliver and Boyd, (1972), section 6.5

### Examples

```
str(Pastes)
require(lattice)
dotplot(cask ~ strength | reorder(batch, strength), Pastes,
        strip = FALSE, strip.left = TRUE, layout = c(1, 10),
        ylab = "Cask within batch",
        xlab = "Paste strength", jitter.y = TRUE)
## Modifying the factors to enhance the plot
Pastes <- within(Pastes, batch <- reorder(batch, strength))
Pastes <- within(Pastes, sample <- reorder(reorder(sample, strength),
        as.numeric(batch)))
dotplot(sample ~ strength | batch, Pastes,
        strip = FALSE, strip.left = TRUE, layout = c(1, 10),
        scales = list(y = list(relation = "free")),
        ylab = "Sample within batch",
```

```

      xlab = "Paste strength", jitter.y = TRUE)
## Four equivalent models differing only in specification
(fm1 <- lmer(strength ~ (1|batch) + (1|sample), Pastes))
(fm2 <- lmer(strength ~ (1|batch/cask), Pastes))
(fm3 <- lmer(strength ~ (1|batch) + (1|batch:cask), Pastes))
(fm4 <- lmer(strength ~ (1|batch/sample), Pastes))
## fm4 results in redundant labels on the sample:batch interaction
head(ranef(fm4)[[1]])
## compare to fm1
head(ranef(fm1)[[1]])
## This model is different and NOT appropriate for these data
(fm5 <- lmer(strength ~ (1|batch) + (1|cask), Pastes))

L <- getME(fm1, "L")
Matrix::image(L, sub = "Structure of random effects interaction in pastes model")

```

---

 Penicillin

*Variation in penicillin testing*


---

### Description

Six samples of penicillin were tested using the *B. subtilis* plate method on each of 24 plates. The response is the diameter (mm) of the zone of inhibition of growth of the organism.

### Format

A data frame with 144 observations on the following 3 variables.

diameter diameter (mm) of the zone of inhibition of the growth of the organism.

plate assay plate. A factor with levels 'a' to 'x'.

sample penicillin sample. A factor with levels 'A' to 'F'.

### Details

The data are described in Davies and Goldsmith (1972) as coming from an investigation to “assess the variability between samples of penicillin by the *B. subtilis* method. In this test method a bulk-inoculated nutrient agar medium is poured into a Petri dish of approximately 90 mm. diameter, known as a plate. When the medium has set, six small hollow cylinders or pots (about 4 mm. in diameter) are cemented onto the surface at equally spaced intervals. A few drops of the penicillin solutions to be compared are placed in the respective cylinders, and the whole plate is placed in an incubator for a given time. Penicillin diffuses from the pots into the agar, and this produces a clear circular zone of inhibition of growth of the organisms, which can be readily measured. The diameter of the zone is related in a known way to the concentration of penicillin in the solution.”

### Source

O.L. Davies and P.L. Goldsmith (eds), *Statistical Methods in Research and Production*, 4th ed., Oliver and Boyd, (1972), section 6.6

**Examples**

```

str(Penicillin)
require(lattice)
dotplot(reorder(plate, diameter) ~ diameter, Penicillin, groups = sample,
        ylab = "Plate", xlab = "Diameter of growth inhibition zone (mm)",
        type = c("p", "a"), auto.key = list(columns = 3, lines = TRUE,
        title = "Penicillin sample"))
(fm1 <- lmer(diameter ~ (1|plate) + (1|sample), Penicillin))

L <- getME(fm1, "L")
Matrix::image(L, main = "L",
              sub = "Penicillin: Structure of random effects interaction")

```

---

plot.lmList4

plots for lmList4 objects

---

**Description**

diagnostic and confidence-interval plots for lmList fits

**Usage**

```

## S3 method for class 'lmList4'
plot(x, form, abline, id, idLabels, grid, ...)
## S3 method for class 'lmList4.confint'
plot(x, y, order, ...)

```

**Arguments**

x	an object inheriting from class <code>lmList</code> , representing a list of <code>lm</code> objects with a common model.
y	ignored: for agreement with generic method
form	an optional formula specifying the desired type of plot. Any variable present in the original data frame used to obtain <code>x</code> can be referenced. In addition, <code>x</code> itself can be referenced in the formula using the symbol <code>"."</code> . Conditional expressions on the right of a <code> </code> operator can be used to define separate panels in a Trellis display. Default is <code>resid(., type = "pool") ~ fitted(.)</code> , corresponding to a plot of the standardized residuals (using a pooled estimate for the residual standard error) versus fitted values.
abline	an optional numeric value, or numeric vector of length two. If given as a single value, a horizontal line will be added to the plot at that coordinate; else, if given as a vector, its values are used as the intercept and slope for a line added to the plot. If missing, no lines are added to the plot.
id	an optional numeric value, or one-sided formula. If given as a value, it is used as a significance level for a two-sided outlier test for the standardized residuals. Observations with absolute standardized residuals greater than the

	$1 - value/2$ quantile of the standard normal distribution are identified in the plot using <code>idLabels</code> . If given as a one-sided formula, its right hand side must evaluate to a logical, integer, or character vector which is used to identify observations in the plot. If missing, no observations are identified.
<code>idLabels</code>	an optional vector, or one-sided formula. If given as a vector, it is converted to character and used to label the observations identified according to <code>id</code> . If given as a one-sided formula, its right hand side must evaluate to a vector which is converted to character and used to label the identified observations. Default is <code>getGroups(x)</code> .
<code>grid</code>	an optional logical value indicating whether a grid should be added to plot. Default depends on the type of Trellis plot used: if <code>xypLOT</code> defaults to TRUE, else defaults to FALSE.
<code>order</code>	which coefficient to order the results by
<code>...</code>	optional arguments passed to the Trellis plot function.

### Details

The plot method for `lmList4` objects is copied from that for `lmList` objects; see [plot.lmList](#) for details.

### Author(s)

Original versions in `nlme` package by Jose Pinheiro and Douglas Bates

### Examples

```
fm.plm <- lmList(Reaction ~ Days | Subject, sleepstudy)
## diagnostic plot: standardized residuals vs. fitted
plot(fm.plm, id=0.05)
ci <- confint(fm.plm)
## plot CIs, ordered by slope (coefficient 2)
plot(ci, order=2, ylab="Subject")
```

---

plot.merMod

*diagnostic plots for merMod fits*

---

### Description

diagnostic plots for `merMod` fits

### Usage

```
## S3 method for class 'merMod'
plot(x,
     form = resid(., type = "pearson") ~ fitted(.), abline,
     id = NULL, idLabels = NULL, grid, ...)
## S3 method for class 'merMod'
qqmath(x, id = NULL, idLabels = NULL, ...)
```



**Arguments**

x	a fitted [ng]lmer model
form	an optional formula specifying the desired type of plot. Any variable present in the original data frame used to obtain x can be referenced. In addition, x itself can be referenced in the formula using the symbol ". ". Conditional expressions on the right of a   operator can be used to define separate panels in a lattice display. Default is <code>resid(., type = "pearson") ~ fitted(.)</code> , corresponding to a plot of the standardized residuals versus fitted values.
abline	an optional numeric value, or numeric vector of length two. If given as a single value, a horizontal line will be added to the plot at that coordinate; else, if given as a vector, its values are used as the intercept and slope for a line added to the plot. If missing, no lines are added to the plot.
id	an optional numeric value, or one-sided formula. If given as a value, it is used as a significance level for a two-sided outlier test for the standardized, or normalized residuals. Observations with absolute standardized (normalized) residuals greater than the $1 - value/2$ quantile of the standard normal distribution are identified in the plot using <code>idLabels</code> . If given as a one-sided formula, its right hand side must evaluate to a logical, integer, or character vector which is used to identify observations in the plot. If missing, no observations are identified.
idLabels	an optional vector, or one-sided formula. If given as a vector, it is converted to character and used to label the observations identified according to <code>id</code> . If given as a vector, it is converted to character and used to label the observations identified according to <code>id</code> . If given as a one-sided formula, its right hand side must evaluate to a vector which is converted to character and used to label the identified observations. Default is the interaction of all the grouping variables in the data frame. The special formula <code>idLabels=~.obs</code> will label the observations according to observation number.
grid	an optional logical value indicating whether a grid should be added to plot. Default depends on the type of lattice plot used: if <code>xypLOT</code> defaults to TRUE, else defaults to FALSE.
...	optional arguments passed to the lattice plot function.

**Details**

Diagnostic plots for the linear mixed-effects fit are obtained. The `form` argument gives considerable flexibility in the type of plot specification. A conditioning expression (on the right side of a | operator) always implies that different panels are used for each level of the conditioning factor, according to a lattice display. If `form` is a one-sided formula, histograms of the variable on the right hand side of the formula, before a | operator, are displayed (the lattice function `histogram` is used). If `form` is two-sided and both its left and right hand side variables are numeric, scatter plots are displayed (the lattice function `xypLOT` is used). Finally, if `form` is two-sided and its left hand side variable is a factor, box-plots of the right hand side variable by the levels of the left hand side variable are displayed (the lattice function `bwplot` is used).

`qqmath` produces a Q-Q plot of the residuals (see `link{qqmath.ranef.mer}` for Q-Q plots of the conditional mode values).

**Author(s)**

original version in nlme package by Jose Pinheiro and Douglas Bates

**Examples**

```
data(Orthodont,package="nlme")
fm1 <- lmer(distance ~ age + (age|Subject), data=Orthodont)
## standardized residuals versus fitted values by gender
plot(fm1, resid(., scaled=TRUE) ~ fitted(.) | Sex, abline = 0)
## box-plots of residuals by Subject
plot(fm1, Subject ~ resid(., scaled=TRUE))
## observed versus fitted values by Subject
plot(fm1, distance ~ fitted(.) | Subject, abline = c(0,1))
## residuals by age, separated by Subject
plot(fm1, resid(., scaled=TRUE) ~ age | Sex, abline = 0)
require("lattice")
qqmath(fm1, id=0.05)
if (require("ggplot2")) {
  ## we can create the same plots using ggplot2 and the fortify() function
  fm1F <- fortify(fm1)
  ggplot(fm1F, aes(.fitted,.resid)) + geom_point(colour="blue") +
    facet_grid(.~Sex) + geom_hline(yintercept=0)
  ## note: Subjects are ordered by mean distance
  ggplot(fm1F, aes(Subject,.resid)) + geom_boxplot() + coord_flip()
  ggplot(fm1F, aes(.fitted,distance))+ geom_point(colour="blue") +
    facet_wrap(~Subject) +geom_abline(intercept=0,slope=1)
  ggplot(fm1F, aes(age,.resid)) + geom_point(colour="blue") + facet_grid(.~Sex) +
    geom_hline(yintercept=0)+geom_line(aes(group=Subject),alpha=0.4)+geom_smooth(method="loess")
  ## (warnings about loess are due to having only 4 unique x values)
  detach("package:ggplot2")
}
```

---

plots.thpr

---

*Mixed-Effects Profile Plots (Regular / Density / Pairs)*


---

**Description**

Xyplot, Densityplot, and Pairs plot methods for a mixed-effects model profile.

xyplot() draws “zeta diagrams”, also visualizing confidence intervals and their asymmetry.

densityplot() draws the profile densities.

sploem() draws profile pairs plots. Contours are for the marginal two-dimensional regions (i.e. using  $df = 2$ ).

**Usage**

```
## S3 method for class 'thpr'
xyplot(x, data = NULL,
       levels = sqrt(qchisq(pmax.int(0, pmin.int(1, conf)), df = 1)),
```

```

      conf = c(50, 80, 90, 95, 99)/100,
      absVal = FALSE, scales=NULL,
      which = 1:nptot, ...)

## S3 method for class 'thpr'
densityplot(x, data, ...)

## S3 method for class 'thpr'
splom(x, data,
      levels = sqrt(qchisq(pmax.int(0, pmin.int(1, conf)), 2)),
      conf = c(50, 80, 90, 95, 99)/100, which = 1:nptot,
      draw.lower = TRUE, draw.upper = TRUE, ...)

```

### Arguments

x	a mixed-effects profile, i.e., of class "thpr", typically resulting from <code>profile(fm)</code> where fm is a fitted model from <code>lmer</code> (or its generalizations).
data	unused - only for compatibility with generic.
levels	the contour levels to be shown; usually derived from conf.
conf	numeric vector of confidence levels to be shown as contours.
absVal	logical indicating if <code>abs(.)</code> olute values should be plotted, often preferred for confidence interval visualization.
scales	plotting options to be passed to <code>xyplot</code>
which	integer or character vector indicating which parameters to profile: default is all parameters (see <code>profile-methods</code> for details).
draw.lower	(logical) draw lower-triangle (zeta scale) panels?
draw.upper	(logical) draw upper-triangle (standard dev/cor scale) panels?
...	further arguments passed to <code>xyplot</code> , <code>densityplot</code> , or <code>splom</code> from package <b>lattice</b> , respectively.

### Value

**xyplot:** a density plot, a "trellis" object (**lattice** package) which when `print()`ed produces plots on the current graphic device.

**densityplot:** a density plot, a "trellis" object, see above.

**splom:** a pairs plot, aka **scatterplot matrix**, a "trellis" object, see above.

### See Also

`profile`, notably for an example.

### Examples

```
## see example("profile.merMod")
```

---

predict.merMod                      *Predictions from a model at new data values*

---

### Description

The `predict` method for `merMod` objects, i.e. results of `lmer()`, `glmer()`, etc.

### Usage

```
## S3 method for class 'merMod'
predict(object, newdata = NULL, newparams = NULL,
        re.form = NULL, ReForm, REForm, REform, terms = NULL,
        type = c("link", "response"), allow.new.levels = FALSE,
        na.action = na.pass, ...)
```

### Arguments

<code>object</code>	a fitted model object
<code>newdata</code>	data frame of for which to evaluate predictions.
<code>newparams</code>	new parameters to use in evaluating predictions, specified as in the <code>start</code> parameter for <code>lmer</code> or <code>glmer</code> – a list with components <code>theta</code> and/or (for GLMMs) <code>beta</code> .
<code>re.form</code>	formula for random effects to condition on. If <code>NULL</code> , include all random effects; if <code>NA</code> or <code>~0</code> , include no random effects
<code>ReForm</code> , <code>REForm</code> , <code>REform</code>	allowed for backward compatibility: <code>re.form</code> is now the preferred argument name.
<code>terms</code>	a <code>terms</code> object - unused at present.
<code>type</code>	character string - either <code>"link"</code> , the default, or <code>"response"</code> indicating the type of prediction object returned.
<code>allow.new.levels</code>	logical if new levels (or <code>NA</code> values) in <code>newdata</code> are allowed. If <code>FALSE</code> (default), such new values in <code>newdata</code> will trigger an error; if <code>TRUE</code> , then the prediction will use the unconditional (population-level) values for data with previously unobserved levels (or <code>NA</code> s).
<code>na.action</code>	<code>function</code> determining what should be done with missing values for fixed effects in <code>newdata</code> . The default is to predict <code>NA</code> : see <code>na.pass</code> .
<code>...</code>	optional additional parameters. None are used at present.

### Value

a numeric vector of predicted values

**Note**

There is no option for computing standard errors of predictions because it is difficult to define an efficient method that incorporates uncertainty in the variance parameters; we recommend [bootMer](#) for this task.

**Examples**

```
(gm1 <- glmer(cbind(incidence, size - incidence) ~ period + (1 |herd), cbpp, binomial))
str(p0 <- predict(gm1))          # fitted values
str(p1 <- predict(gm1,re.form=NA)) # fitted values, unconditional (level-0)
newdata <- with(cbpp, expand.grid(period=unique(period), herd=unique(herd)))
str(p2 <- predict(gm1,newdata))  # new data, all RE
str(p3 <- predict(gm1,newdata,re.form=NA)) # new data, level-0
str(p4 <- predict(gm1,newdata,re.form= ~(1|herd))) # explicitly specify RE
stopifnot(identical(p2, p4))
```

---

 profile-methods

*Profile method for merMod objects*


---

**Description**

Methods for [profile\(\)](#) of [\[ng\]lmer](#) fitted models.

The [log\(\)](#) method and the more flexible [logProf\(\)](#) utility transform a lmer profile into one where logarithms of standard deviations are used; see [Details](#).

**Usage**

```
## S3 method for class 'merMod'
profile(fitted, which = NULL, alphamax = 0.01,
maxpts = 100, delta = NULL,
      delta.cutoff = 1/8, verbose = 0, devtol = 1e-09,
      maxmult = 10, startmethod = "prev", optimizer = NULL,
      control=NULL, signames = TRUE,
      parallel = c("no", "multicore", "snow"),
      ncpus = getOption("profile.ncpus", 1L), cl = NULL, ...)
## S3 method for class 'thpr'
as.data.frame(x, ...)
## S3 method for class 'thpr'
log(x, base = exp(1))
logProf(x, base = exp(1), ranef = TRUE,
      sigIni = if(ranef) "sig" else "sigma")
```

**Arguments**

fitted	a fitted model, e.g., the result of <code>lmer(. .)</code> .
which	NULL value, integer or character vector indicating which parameters to profile: default (NULL) is all parameters. For integer, i.e., indexing, the parameters are ordered as follows: <ol style="list-style-type: none"> <li>(1) random effects (theta) parameters; these are ordered as in <code>getME(. , "theta")</code>, i.e., as the lower triangle of a matrix with standard deviations on the diagonal and correlations off the diagonal.</li> <li>(2) residual standard deviation (or scale parameter for GLMMs where appropriate).</li> <li>(3) fixed effect (beta) parameters.</li> </ol> Alternatively, which may be a character, containing "beta_" or "theta_" denoting the fixed or random effects parameters, respectively, or also containing parameter names, such as ".sigma" or "(Intercept)".
alphamax	a number in (0, 1), such that $1 - \text{alphamax}$ is the maximum alpha value for likelihood ratio confidence regions; used to establish the range of values to be profiled.
maxpts	maximum number of points (in each direction, for each parameter) to evaluate in attempting to construct the profile.
delta	stepping scale for deciding on next point to profile. The code uses the local derivative of the profile at the current step to establish a change in the focal parameter that will lead to a step of delta on the square-root-deviance scale. If NULL, the <code>delta.cutoff</code> parameter will be used to determine the stepping scale.
delta.cutoff	stepping scale (see <code>delta</code> ) expressed as a fraction of the target maximum value of the profile on the square-root-deviance scale. Thus a <code>delta.cutoff</code> setting of $1/n$ will lead to a profile with approximately $2*n$ calculated points for each parameter (i.e., $n$ points in each direction, below and above the estimate for each parameter).
verbose	level of output from internal calculations.
devtol	tolerance for fitted deviances less than baseline (supposedly minimum) deviance.
maxmult	maximum multiplier of the original step size allowed, defaults to 10.
startmethod	method for picking starting conditions for optimization (STUB).
optimizer	(character or function) optimizer to use (see <code>lmer</code> for details); default is to use the optimizer from the original model fit.
control	a <code>list</code> of options controlling the profiling (see <code>lmerControl</code> ): default is to use the control settings from the original model fit.
signames	logical indicating if abbreviated names of the form <code>.sigNN</code> should be used; otherwise, names are more meaningful (but longer) of the form <code>(sd cor)_(effects) (group)</code> . Note that some code for profile transformations (e.g., <code>log()</code> or <code>varianceProf</code> ) depends on <code>signames==TRUE</code> .
...	potential further arguments for various methods.
x	an object of class <code>thpr</code> (i.e., output of profile)
base	the base of the logarithm. Defaults to natural logarithms.

ranef	logical indicating if the sigmas of the random effects should be <code>log()</code> transformed as well. If false, only $\sigma$ (standard deviation of errors) is transformed.
sigIni	character string specifying the initial part of the sigma parameters to be log transformed.
parallel	The type of parallel operation to be used (if any). If missing, the default is taken from the option <code>"profile.parallel"</code> (and if that is not set, "no").
ncpus	integer: number of processes to be used in parallel operation: typically one would choose this to be the number of available CPUs.
cl	An optional <b>parallel</b> or <b>snow</b> cluster for use if <code>parallel = "snow"</code> . If not supplied, a cluster on the local machine is created for the duration of the profile call.

### Details

The `log` method and the more flexible `logProf()` function transform the profile into one where  $\log(\sigma)$  is used instead of  $\sigma$ . By default all sigmas including the standard deviations of the random effects are transformed i.e., the methods return a profile with all of the `.sigNN` parameters replaced by `.lsigNN`. If `ranef` is false, only `".sigma"`, the standard deviation of the errors, is transformed (as it should never be zero, whereas random effect standard deviations (`.sigNN`) can be reasonably be zero).

The forward and backward splines for the log-transformed parameters are recalculated.

Methods for function `profile` (package `stats`), here for profiling (fitted) mixed effect models.

### Value

`profile(<merMod>)` returns an object of S3 class `"thpr"`, which is `data.frame`-like. Notable methods for such a profile object `confint()`, which returns the confidence intervals based on the profile, and three plotting methods (which require the `lattice` package), `xyplot`, `densityplot`, and `splom`.

In addition, the `log()` (see above) and `as.data.frame()` methods can transform `"thpr"` objects in useful ways.

### See Also

The plotting methods `xyplot` etc, for class `"thpr"`; `varianceProf` for transformation (from st.dev.) to variance scale.

For (more expensive) alternative confidence intervals: `bootMer`.

### Examples

```
fm01ML <- lmer(Yield ~ 1|Batch, Dyestuff, REML = FALSE)
system.time(
  tpr <- profile(fm01ML, optimizer="Nelder_Mead", which="beta_")
)## fast; as only *one* beta parameter is profiled over
## full profiling (default which means 'all) needs
## ~2.6s (on a 2010 Macbook Pro)
system.time( tpr <- profile(fm01ML))
## ~1s, + possible warning about bobyqa convergence
```

```

(confint(tpr) -> CIpr)

stopifnot(all.equal(unnamed(CIpr),
  array(c(12.1985292, 38.2299848, 1486.4515,
          84.0630513, 67.6576964, 1568.54849), dim = 3:2),
        tol= 1e-07))# 1.37e-9 {64b}

library("lattice")
xyplot(tpr)
xyplot(tpr, absVal=TRUE) # easier to see conf.int.s (and check symmetry)
xyplot(tpr, conf = c(0.95, 0.99), # (instead of all five 50, 80,...)
      main = "95% and 99% profile() intervals")
xyplot(logProf(tpr, ranef=FALSE),
      main = expression("lmer profile()s" ~ log(sigma)*" (only log)"))
densityplot(tpr, main="densityplot( profile(lmer(..) )")
densityplot(varianceProf(tpr), main=" varianceProf( profile(lmer(..) )")
splom(tpr)
splom(logProf(tpr, ranef=FALSE))
doMore <- lme4::testLevel() > 1
if(doMore) { ## not typically, for time constraint reasons
  ## Batch and residual variance only
  system.time(tpr2 <- profile(fm01ML, which=1:2, optimizer="Nelder_Mead"))
  print( xyplot(tpr2) )
  print( xyplot(log(tpr2)) )# log(sigma) is better
  print( xyplot(logProf(tpr2, ranef=FALSE)) )

  ## GLMM example
  gm1 <- glmer(cbind(incidence, size - incidence) ~ period + (1 | herd),
    data = cbpp, family = binomial)
  ## running ~ 10-12 seconds on a modern machine {-> "verbose" while you wait}:
  print( system.time(pr4 <- profile(gm1, verbose=TRUE)) )
  print( xyplot(pr4, layout=c(5,1), as.table=TRUE) )
  print( xyplot(log(pr4), absVal=TRUE) ) # log(sigma_1)
  print( splom(pr4) )
  print( system.time( # quicker: only sig01 and one fixed effect
    pr2 <- profile(gm1, which=c("theta_", "period2"))))
  print( confint(pr2) )
  ## delta.: higher underlying resolution, only for 'sigma_1':
  print( system.time(
    pr4.hr <- profile(gm1, which="theta_", delta.cutoff=1/16))
  print( xyplot(pr4.hr) )
}

```

## Description

The `print`, `summary` methods (including the `print` for the `summary()` result) in **lme4** are modular, using about ten small utility functions. Other packages, building on **lme4** can use the same utilities for ease of programming and consistency of output.



Notably see the Examples.

`llikAIC()` extracts the log likelihood, AIC, and related statics from a Fitted LMM.

`formatVC()` “format()”s the `VarCorr` matrix of the random effects – for `print()`ing and `show()`ing; it is also the “workhorse” of `.prt.VC()`, and returns a `character` matrix.

`.prt.*()` all use `cat` and `print` to produce output.

## Usage

```
llikAIC(object, devianceFUN = devCrit, chkREML = TRUE,
        devcomp = object@devcomp)
```

```
methTitle(dims)
```

```
.prt.methTit(mtit, class)
.prt.family (famL)
.prt.resids (resids, digits, title = "Scaled residuals:", ...)
.prt.call   (call, long = TRUE)
.prt.aictab (aictab, digits = 1)
.prt.grps   (ngrps, nobs)
.prt.warn   (optinfo, summary = FALSE, ...)
```

```
.prt.VC (varcor, digits, comp, formatter = format, ...)
formatVC(varcor, digits = max(3, getOption("digits") - 2),
        comp = "Std.Dev.", formatter = format,
        useScale = attr(varcor, "useSc"), ...)
```

## Arguments

<code>object</code>	a LMM model fit
<code>devianceFUN</code>	the function to be used for computing the deviance; should not be changed for <b>lme4</b> created objects.
<code>chkREML</code>	optional logical indicating if <code>object</code> maybe a REML fit.
<code>devcomp</code>	for <b>lme4</b> always the equivalent of <code>object@devcomp</code> ; here a <code>list</code>
<code>dims</code>	for <b>lme4</b> always the equivalent of <code>object@devcomp\$dims</code> , a named vector or list with components "GLMM", "NLMM", "REML", and "nAGQ" of which the first two are <code>logical</code> scalars, and the latter two typically are <code>FALSE</code> or <code>numeric</code> .
<code>mtit</code>	the result of <code>methTitle(object)</code>
<code>class</code>	typically <code>class(object)</code> .
<code>famL</code>	a <code>list</code> with components family and link, each a <code>character</code> string; note that standard R <code>family</code> objects can be used directly, as well.
<code>resids</code>	numeric vector of model residuals.
<code>digits</code>	non-negative integer of (significant) digits to print minimally.
<code>title</code>	<code>character</code> string.
<code>...</code>	optional arguments passed on, e.g., to <code>residuals()</code> .

call	the <code>call</code> of the model fit; e.g., available via (generic) function <code>getCall()</code> .
long	logical indicating if the output may be long, e.g., printing the control part of the call if there is one.
aictab	typically the AICTab component of the result of <code>llikAIC()</code> .
varcor	typically the result of <code>VarCorr()</code> .
comp	optional ...
formatter	a <code>function</code> used for formatting the numbers.
ngrps	integer (vector), typically the result of <code>ngrps(object)</code> .
nobs	integer; the number of observations, e.g., the result of <code>nobs</code> .
optinfo	typically object <code>@ optinfo</code> , the optimization infos, including warnings if there were.
summary	logical
useScale	(logical) whether the parent model estimates a scale parameter

### Value

`llikAIC()` returns a `list` with components

`logLik` which is `logLik(object)`, and

`AICTab` a “table” of `AIC`, `BIC`, `logLik`, deviance and `df.residual()` values.

### Examples

```
## Create a few "lme4 standard" models -----
fm1 <- lmer(Reaction ~ Days + (Days | Subject), sleepstudy)
fmM <- update(fm1, REML=FALSE) # -> Maximum Likelihood

gm1 <- glmer(cbind(incidence, size - incidence) ~ period + (1 | herd),
             data = cbpp, family = binomial)
gmA <- update(gm1, nAGQ = 5)

(lA1 <- llikAIC(fm1))
(lAM <- llikAIC(fmM))
(lAg <- llikAIC(gmA))

(m1 <- methTitle(fm1 @ devcomp $ dims))
(mM <- methTitle(fmM @ devcomp $ dims))
(mG <- methTitle(gm1 @ devcomp $ dims))
(mA <- methTitle(gmA @ devcomp $ dims))

.prt.methTit(m1, class(fm1))
.prt.methTit(mA, class(gmA))

.prt.family(gaussian())
.prt.family(binomial())
.prt.family( poisson())
```

```

.prt.resids(residuals(fm1), digits = 4)
.prt.resids(residuals(fmM), digits = 2)

.prt.call(getCall(fm1))
.prt.call(getCall(gm1))

.prt.aictab ( lA1 $ AICtab ) # REML
.prt.aictab ( lAM $ AICtab ) # ML --> AIC, BIC, ...

V1 <- VarCorr(fm1)
m <- formatVC(V1)
stopifnot(is.matrix(m), is.character(m), ncol(m) == 4)
print(m, quote = FALSE) ## prints all but the first line of .prt.VC() below:
.prt.VC( V1, digits = 4, formatter = format)
## Random effects:
## Groups   Name          Std.Dev. Corr
## Subject  (Intercept) 24.740
##          Days         5.922  0.07
## Residual                25.592

p1 <- capture.output(V1)
p2 <- capture.output( print(m, quote=FALSE) )
pX <- capture.output( .prt.VC(V1, digits = max(3, getOption("digits")-2)) )
stopifnot(identical(p1, p2),
          identical(p1, pX[-1])) # [-1] : dropping 1st line

.prt.grps(ngrps = ngrps(fm1),
          nobs = nobs (fm1))
## --> Number of obs: 180, groups: Subject, 18

.prt.warn(fm1 @ optinfo) # nothing .. had no warnings

```

## Description

One of the most frequently asked questions about lme4 is "how do I calculate p-values for estimated parameters?" Previous versions of lme4 provided the `mcmcSamp` function, which efficiently generated a Markov chain Monte Carlo sample from the posterior distribution of the parameters, assuming flat (scaled likelihood) priors. Due to difficulty in constructing a version of `mcmcSamp` that was reliable even in cases where the estimated random effect variances were near zero (e.g. <https://stat.ethz.ch/pipermail/r-sig-mixed-models/2009q4/003115.html>), `mcmcSamp` has been withdrawn (or more precisely, not updated to work with lme4 versions  $\geq 1.0.0$ ).

Many users, including users of the `aovLmer.fnc` function from the `languageR` package which relies on `mcmcSamp`, will be deeply disappointed by this lacuna. Users who need p-values have a variety of options. In the list below, the methods marked MC provide explicit model comparisons; CI denotes confidence intervals; and P denotes parameter-level or sequential tests of all effects in a model. The starred (\*) suggestions provide finite-size corrections (important when the number of groups is  $< 50$ ); those marked (+) support GLMMs as well as LMMs.

- likelihood ratio tests via `anova` or `drop1` (MC,+)
- profile confidence intervals via `profile.merMod` and `confint.merMod` (CI,+)
- parametric bootstrap confidence intervals and model comparisons via `bootMer` (or `PBmodcomp` in the `pbkrtest` package) (MC/CI,\*,+)
- for random effects, simulation tests via the `RLRsim` package (MC,\*)
- for fixed effects, F tests via Kenward-Roger approximation using `KRmodcomp` from the `pbkrtest` package (MC,\*)
- `car::Anova` and `lmerTest::anova` provide wrappers for Kenward-Roger-corrected tests using `pbkrtest`: `lmerTest::anova` also provides t tests via the Satterthwaite approximation (P,\*)
- `afex::mixed` is another wrapper for `pbkrtest` and `anova` providing "Type 3" tests of all effects (P,\*,+)

`arm::sim`, or `bootMer`, can be used to compute confidence intervals on predictions.

For `glmer` models, the `summary` output provides p-values based on asymptotic Wald tests (P); while this is standard practice for generalized linear models, these tests make assumptions both about the shape of the log-likelihood surface and about the accuracy of a chi-squared approximation to differences in log-likelihoods.

When all else fails, don't forget to keep p-values in perspective: <http://www.phdcomics.com/comics/archive.php?comid=905>

---

ranef

*Extract the modes of the random effects*

---

## Description

A generic function to extract the conditional modes of the random effects from a fitted model object. For linear mixed models the conditional modes of the random effects are also the conditional means.

## Usage

```
## S3 method for class 'merMod'
ranef(object, condVar = FALSE,
      drop = FALSE, which1 = names(ans), postVar=FALSE, ...)
## S3 method for class 'ranef.mer'
dotplot(x, data, main=TRUE, ...)
## S3 method for class 'ranef.mer'
qqmath(x, data, main=TRUE, ...)
```

## Arguments

<code>object</code>	an object of a class of fitted models with random effects, typically a <code>merMod</code> object.
<code>condVar</code>	an optional logical argument indicating if the conditional variance-covariance matrices of the random effects should be added as an attribute.

drop	should components of the return value that would be data frames with a single column, usually a column called '(Intercept)', be returned as named vectors instead?
which1	character vector of names of grouping factors for which the random effects should be returned.
postVar	a (deprecated) synonym for condVar
x	a random-effects object (of class <code>ranef.mer</code> ) produced by <code>ranef</code>
main	include a main title, indicating the grouping factor, on each sub-plot?
data	This argument is required by the <code>dotplot</code> and <code>qqmath</code> generic methods, but is not actually used.
...	some methods for these generic functions require additional arguments.

### Details

If grouping factor  $i$  has  $k$  levels and  $j$  random effects per level the  $i$ th component of the list returned by `ranef` is a data frame with  $k$  rows and  $j$  columns. If `condVar` is `TRUE` the "postVar" attribute is an array of dimension  $j$  by  $j$  by  $k$ . The  $k$ th face of this array is a positive definite symmetric  $j$  by  $j$  matrix. If there is only one grouping factor in the model the variance-covariance matrix for the entire random effects vector, conditional on the estimates of the model parameters and on the data will be block diagonal and this  $j$  by  $j$  matrix is the  $k$ th diagonal block. With multiple grouping factors the faces of the "postVar" attributes are still the diagonal blocks of this conditional variance-covariance matrix but the matrix itself is no longer block diagonal.

### Value

An object of class `ranef.mer` composed of a list of data frames, one for each grouping factor for the random effects. The number of rows in the data frame is the number of levels of the grouping factor. The number of columns is the dimension of the random effect associated with each level of the factor.

If `condVar` is `TRUE` each of the data frames has an attribute called "postVar" which is a three-dimensional array with symmetric faces; each face contains the variance-covariance matrix for a particular level of the grouping factor. (The name of this attribute is a historical artifact, and may be changed to `condVar` at some point in the future.)

When `drop` is `TRUE` any components that would be data frames of a single column are converted to named numeric vectors.

### Note

To produce a (list of) "caterpillar plots" of the random effects apply `dotplot` to the result of a call to `ranef` with `condVar = TRUE`; `qqmath` will generate a list of Q-Q plots.

### Examples

```
require(lattice)
fm1 <- lmer(Reaction ~ Days + (Days|Subject), sleepstudy)
fm2 <- lmer(Reaction ~ Days + (1|Subject) + (0+Days|Subject), sleepstudy)
fm3 <- lmer(diameter ~ (1|plate) + (1|sample), Penicillin)
```

```

ranef(fm1)
str(rr1 <- ranef(fm1, condVar = TRUE))
dotplot(rr1) ## default
## specify free scales in order to make Day effects more visible
dotplot(rr1,scales = list(x = list(relation = 'free'))[["Subject"]])
if(FALSE) { ##-- condVar=TRUE is not yet implemented for multiple terms -- FIXME
str(ranef(fm2, condVar = TRUE))
}
op <- options(digits = 4)
ranef(fm3, drop = TRUE)
options(op)

```

---

refit

*Refit a (merMod) Model with a Different Response*


---

### Description

Refit a model, possibly after modifying the response vector. This makes use of the model representation and directly goes to the optimization.

### Usage

```

refit(object, newresp, ...)

## S3 method for class 'merMod'
refit(object, newresp = NULL, rename.response = FALSE,
      maxit = 100, ...)

```

### Arguments

<code>object</code>	a fitted model, usually of class <code>lmerMod</code> , to be refit with a new response.
<code>newresp</code>	an (optional) numeric vector providing the new response, of the same length as the original response (see <code>Details</code> for information on NA handling). May also be a data frame with a single numeric column, e.g. as produced by <code>simulate(object)</code> .
<code>rename.response</code>	when refitting the model, should the name of the response variable in the formula and model frame be replaced with the name of <code>newresp</code> ?
<code>maxit</code>	scalar integer, currently only for GLMMs: the maximal number of Pwrss update iterations.
<code>...</code>	optional additional parameters. For the <code>merMod</code> method, <code>control</code> .

### Details

Refit a model, possibly after modifying the response vector. This could be done using `update()`, but the `refit()` approach should be faster because it bypasses the creation of the model representation and goes directly to the optimization step.

Setting `rename.response = TRUE` may be necessary if one wants to do further operations (such as `update`) on the fitted model. However, the refitted model will still be slightly different from the equivalent model fitted via `update`; in particular, the terms component is not updated to reflect the new response variable, if it has a different name from the original.

If `newresp` has an `na.action` attribute, then it is assumed that NA values have already been removed from the numeric vector; this allows the results of `simulate(object)` to be used even if the original response vector contained NA values. Otherwise, the length of `newresp` must be the same as the *original* length of the response.

## Value

an object like `x`, but fit to a different response vector  $Y$ .

## See Also

[update.merMod](#) for more flexible and extensive model refitting; [refitML](#) for refitting a REML fitted model with maximum likelihood ('ML').

## Examples

```
## Ex. 1: using refit() to fit each column in a matrix of responses -----
set.seed(101)
Y <- matrix(rnorm(1000),ncol=10)
## combine first column of responses with predictor variables
d <- data.frame(y=Y[,1],x=rnorm(100),f=rep(1:10,10))
## (use check.conv.grad="ignore" to disable convergence checks because we
## are using a fake example)
## fit first response
fit1 <- lmer(y ~ x+(1|f), data = d,
            control= lmerControl(check.conv.grad="ignore",
                                check.conv.hess="ignore"))
## combine fit to first response with fits to remaining responses
res <- c(fit1,lapply(as.data.frame(Y[,-1]), refit, object=fit1))

## Ex. 2: refitting simulated data using data that contain NA values -----
sleepstudyNA <- sleepstudy
sleepstudyNA$Reaction[1:3] <- NA
fm0 <- lmer(Reaction ~ Days + (1|Subject), sleepstudyNA)
## the special case of refitting with a single simulation works ...
ss0 <- refit(fm0, simulate(fm0))
## ... but if simulating multiple responses (for efficiency),
## need to use na.action=na.exclude in order to have proper length of data
fm1 <- lmer(Reaction ~ Days + (1|Subject), sleepstudyNA, na.action=na.exclude)
ss <- simulate(fm1, 5)
res2 <- refit(fm1, ss[[5]])
```

---

 refitML

*Refit a Model by Maximum Likelihood Criterion*


---

### Description

Refit a (`merMod`) model using the maximum likelihood criterion.

### Usage

```
refitML(x, ...)
## S3 method for class 'merMod'
refitML(x, optimizer = "bobyqa", ...)
```

### Arguments

<code>x</code>	a fitted model, usually of class " <code>lmerMod</code> ", to be refit according to the maximum likelihood criterion.
<code>...</code>	optional additional parameters. None are used at present.
<code>optimizer</code>	a string indicating the optimizer to be used.

### Details

This function is primarily used to get a maximum likelihood fit of a linear mixed-effects model for an [anova](#) comparison.

### Value

an object like `x` but fit by maximum likelihood

### See Also

[refit](#) and [update.merMod](#) for more extensive refitting.

---

 rePos

*Generator object for the rePos (random-effects positions) class*


---

### Description

The generator object for the [rePos](#) class used to determine the positions and orders of random effects associated with particular random-effects terms in the model.

### Usage

```
rePos(...)
```



**Arguments**

...                   Argument list (see Note).

**Methods**

new(mer=mer) Create a new `rePos` object.

**Note**

Arguments to the new methods must be named arguments. `mer`, an object of class "`merMod`", is the only required/expected argument.

**See Also**

`rePos`

---

rePos-class

*Class "rePos"*


---

**Description**

A reference class for determining the positions in the random-effects vector that correspond to particular random-effects terms in the model formula

**Extends**

All reference classes extend and inherit methods from "`envRefClass`".

**Examples**

```
showClass("rePos")
```

---

residuals.merMod

*residuals of merMod objects*


---

**Description**

residuals of merMod objects

**Usage**

```
## S3 method for class 'merMod'
residuals(object,
  type = if (isGLMM(object)) "deviance" else "response",
  scaled = FALSE, ...)

## S3 method for class 'lmResp'
residuals(object,
  type = c("working", "response", "deviance", "pearson", "partial"),
  ...)

## S3 method for class 'glmResp'
residuals(object,
  type = c("deviance", "pearson", "working", "response", "partial"),
  ...)
```

**Arguments**

object	a fitted [g]lmer (merMod) object
type	type of residuals
scaled	scale residuals by residual standard deviation (=scale parameter)?
...	additional arguments (ignored: for method compatibility)

**Details**

- The default residual type varies between lmerMod and glmerMod objects: they try to mimic `residuals.lm` and `residuals.glm` respectively. In particular, the default type is "response", i.e. (observed-fitted) for lmerMod objects vs. "deviance" for glmerMod objects. type="partial" is not yet implemented for either type.
- Note that the meaning of "pearson" residuals differs between `residuals.lm` and `residuals.lme`. The former returns values scaled by the square root of user-specified weights (if any), but *not* by the residual standard deviation, while the latter returns values scaled by the estimated standard deviation (which will include the effects of any variance structure specified in the weights argument). To replicate lme behaviour, use type="pearson", scaled=TRUE.

---

sigma

---

*Extract Residual Standard Deviation 'Sigma'*


---

**Description**

Extract the estimated standard deviation of the errors, the “residual standard deviation” (also mis-named the “residual standard error”), from a fitted model.

**Usage**

```
## S3 method for class 'merMod'
sigma(object, ...)
```

**Arguments**

object            a fitted model.  
 ...                additional, optional arguments, passed from or to methods. (None currently in our two methods.)

**Details**

Package **lme4** provides methods for mixed-effects models of class **merMod** and lists of linear models, **lmList4**.

**Value**

Typically a number, the estimated standard deviation of the errors (“residual standard deviation”) for Gaussian models, and - less interpretably - the square root of the residual deviance per degree of freedom in more general models.

**Examples**

```
methods(sigma)# from R 3.3.0 on, shows methods from pkgs 'stats' *and* 'lme4'
```

---

simulate.merMod	<i>Simulate Responses From merMod Object</i>
-----------------	--

---

**Description**

Simulate responses from a “merMod” fitted model object, i.e., from the model represented by it.

**Usage**

```
## S3 method for class 'merMod'
simulate(object, nsim = 1, seed = NULL,
  use.u = FALSE, re.form = NA, ReForm, REForm, REform,
  newdata=NULL, newparams=NULL, family=NULL,
  allow.new.levels = FALSE, na.action = na.pass, ...)

## S3 method for class 'formula'
simulate(object, nsim = 1, seed = NULL,
  family, weights=NULL, offset=NULL, ...)

.simulateFun(object, nsim = 1, seed = NULL, use.u = FALSE,
  re.form = NA, ReForm, REForm, REform,
  newdata=NULL, newparams=NULL,
  formula=NULL, family=NULL, weights=NULL, offset=NULL,
  allow.new.levels = FALSE, na.action = na.pass, ...)
```

**Arguments**

object	(for simulate.merMod) a fitted model object or (for simulate.formula) a (one-sided) mixed model formula, as described for <a href="#">lmer</a> .
nsim	positive integer scalar - the number of responses to simulate.
seed	an optional seed to be used in <a href="#">set.seed</a> immediately before the simulation so as to generate a reproducible sample.
use.u	(logical) if TRUE, generate a simulation conditional on the current random-effects estimates; if FALSE generate new Normally distributed random-effects values. (Redundant with re.form, which is preferred: TRUE corresponds to re.form = NULL (condition on all random effects), while FALSE corresponds to re.form = ~0 (condition on none of the random effects).)
re.form	formula for random effects to condition on. If NULL, condition on all random effects; if NA or ~0, condition on no random effects. See Details.
ReForm, REForm, REform	deprecated: re.form is now the preferred argument name.
newdata	data frame for which to evaluate predictions.
newparams	new parameters to use in evaluating predictions, specified as in the start parameter for <a href="#">lmer</a> or <a href="#">glmer</a> – a list with components theta and beta and (for LMMs or GLMMs that estimate a scale parameter) sigma
formula	a (one-sided) mixed model formula, as described for <a href="#">lmer</a> .
family	a GLM family, as in <a href="#">glmer</a> .
weights	prior weights, as in <a href="#">lmer</a> or <a href="#">glmer</a> .
offset	offset, as in <a href="#">glmer</a> .
allow.new.levels	(logical) if FALSE (default), then any new levels (or NA values) detected in newdata will trigger an error; if TRUE, then the prediction will use the unconditional (population-level) values for data with previously unobserved levels (or NAs).
na.action	what to do with NA values in new data: see <a href="#">na.fail</a>
...	optional additional arguments: none are used at present.

**Details**

- ordinarily `simulate` is used to generate new values from an existing, fitted model (`merMod` object): however, if `formula`, `newdata`, and `newparams` are specified, `simulate` generates the appropriate model structure to simulate from.
- The `re.form` argument allows the user to specify how the random effects are incorporated in the simulation. All of the random effects terms included in `re.form` will be *conditioned on* - that is, the conditional modes of those random effects will be included in the deterministic part of the simulation. (If new levels are used (and `allow.new.levels` is TRUE), the conditional modes for these levels will be set to the population mode, i.e. values of zero will be used for the random effects.) Conversely, the random effect terms that are *not* included in `re.form` will be *simulated from* - that is, new values will be chosen for each group based on the estimated random-effects variances.

The default behaviour (using `re.form=NA`) is to condition on none of the random effects, simulating new values for all of the random effects.

- For Gaussian fits, `sigma` specifies the residual standard deviation; for Gamma fits, it specifies the shape parameter (the rate parameter for each observation  $i$  is calculated as `shape/mean(i)`). For negative binomial fits, the overdispersion parameter is specified via the family, e.g. `simulate(..., family=negat`.

### See Also

[bootMer](#) for “simulestimate”, i.e., where each simulation is followed by refitting the model.

### Examples

```
## test whether fitted models are consistent with the
## observed number of zeros in CBPP data set:
gm1 <- glmer(cbind(incidence, size - incidence) ~ period + (1 | herd),
             data = cbpp, family = binomial)
gg <- simulate(gm1,1000)
zeros <- sapply(gg,function(x) sum(x[,"incidence"]==0))
plot(table(zeros))
abline(v=sum(cbpp$incidence==0),col=2)
##
## simulate from a non-fitted model; in this case we are just
## replicating the previous model, but
params <- list(theta=0.5,beta=c(2,-1,-2,-3))
simdat <- with(cbpp,expand.grid(herd=levels(herd),period=factor(1:4)))
simdat$size <- 15
simdat$incidence <- sample(0:1,size=nrow(simdat),replace=TRUE)
form <- formula(gm1)[-2]
simulate(form,newdata=simdat,family=binomial,
         newparams=params)
```

---

sleepstudy

*Reaction times in a sleep deprivation study*

---

### Description

The average reaction time per day for subjects in a sleep deprivation study. On day 0 the subjects had their normal amount of sleep. Starting that night they were restricted to 3 hours of sleep per night. The observations represent the average reaction time on a series of tests given each day to each subject.

### Format

A data frame with 180 observations on the following 3 variables.

Reaction Average reaction time (ms)

Days Number of days of sleep deprivation

Subject Subject number on which the observation was made.

**Details**

These data are from the study described in Belenky et al. (2003), for the sleep-deprived group and for the first 10 days of the study, up to the recovery period.

**References**

Gregory Belenky, Nancy J. Wesensten, David R. Thorne, Maria L. Thomas, Helen C. Sing, Daniel P. Redmond, Michael B. Russo and Thomas J. Balkin (2003) Patterns of performance degradation and restoration during sleep restriction and subsequent recovery: a sleep dose-response study. *Journal of Sleep Research* **12**, 1–12.

**Examples**

```
str(sleepstudy)
require(lattice)
xyplot(Reaction ~ Days | Subject, sleepstudy, type = c("g","p","r"),
       index = function(x,y) coef(lm(y ~ x))[1],
       xlab = "Days of sleep deprivation",
       ylab = "Average reaction time (ms)", aspect = "xy")
(fm1 <- lmer(Reaction ~ Days + (Days|Subject), sleepstudy))
(fm2 <- lmer(Reaction ~ Days + (1|Subject) + (0+Days|Subject), sleepstudy))
```

---

subbars

---

*"Sub[ststitute] Bars"*


---

**Description**

Substitute the '+' function for the '|' function in a mixed-model formula, recursively (hence the argument name term). This provides a formula suitable for the current `model.frame` function.

**Usage**

```
subbars(term)
```

**Arguments**

term            a mixed-model formula

**Value**

the formula with all | operators replaced by +

**See Also**

`formula`, `model.frame`, `model.matrix`.

Other utilities: `findbars`, `nobars`, `mkRespMod`, `mkReTrms`, `nlformula`.

## Examples

```
subbars(Reaction ~ Days + (Days|Subject)) ## => Reaction ~ Days + (Days + Subject)
```

---

troubleshooting	<i>Troubleshooting</i>
-----------------	------------------------

---

## Description

This page attempts to summarize some of the common problems with fitting [gn]lmer models and how to troubleshoot them.

- failure to converge in (xxxx) evaluations The optimizer hit its maximum limit of function evaluations. To increase this, use the `optControl` argument of `[g]lmerControl` – for Nelder\_Mead and bobyqa the relevant parameter is `maxfun`; for `optim` and `optimx`-wrapped optimizers, including `nlminwrap`, it's `maxit`; for `nloptwrap`, it's `maxeval`.
- Model failed to converge with `max|grad| ...`. The scaled gradient at the fitted (RE)ML estimates is worryingly large. Try
  - refitting the parameters starting at the current estimates: getting consistent results (with no warning) suggests a false positive
  - switching optimizers: getting consistent results suggests there is not really a problem; getting a similar log-likelihood with different parameter estimates suggests that the parameters are poorly determined (possibly the result of a misspecified or overfitted model)
  - compute values of the deviance in the neighbourhood of the estimated parameters to double-check that `lme4` has really found a local optimum.
- Hessian is numerically singular: parameters are not uniquely determined The Hessian (inverse curvature matrix) at the maximum likelihood or REML estimates has a very large eigenvalue, indicating that (within numerical tolerances) the surface is completely flat in some direction. The model may be misspecified, or extremely badly scaled (see "Model is nearly unidentifiable").
- Model is nearly unidentifiable ... Rescale variables? The Hessian (inverse curvature matrix) at the maximum likelihood or REML estimates has a large eigenvalue, indicating that the surface is nearly flat in some direction. Consider centering and/or scaling continuous predictor variables.
- Contrasts can be applied only to factors with 2 or more levels One or more of the categorical predictors in the model has fewer than two levels. This may be due to user error when converting these predictors to factors prior to modeling, or it may result from some factor levels being eliminated due to NAs in other predictors. Double-check the number of data points in each factor level to see which one is the culprit: `lapply(na.omit(df[, vars]), table)` (where `df` is the data frame and `vars` are the column names of your predictor variables).

**Description**

This function calculates the estimated variances, standard deviations, and correlations between the random-effects terms in a mixed-effects model, of class `merMod` (linear, generalized or nonlinear). The within-group error variance and standard deviation are also calculated.

**Usage**

```
## S3 method for class 'merMod'
VarCorr(x, sigma=1, ...)

## S3 method for class 'VarCorr.merMod'
as.data.frame(x, row.names = NULL,
              optional = FALSE, order = c("cov.last", "lower.tri"), ...)
## S3 method for class 'VarCorr.merMod'
print(x, digits = max(3, getOption("digits") - 2),
      comp = "Std.Dev.", formatter = format, ...)
```

**Arguments**

<code>x</code>	for <code>VarCorr</code> : a fitted model object, usually an object inheriting from class <code>merMod</code> . For <code>as.data.frame</code> , a <code>VarCorr.merMod</code> object returned from <code>VarCorr</code> .
<code>sigma</code>	an optional numeric value used as a multiplier for the standard deviations.
<code>digits</code>	an optional integer value specifying the number of digits
<code>order</code>	arrange data frame with variances/standard deviations first and covariances/correlations last for each random effects term (" <code>cov.last</code> "), or in the order of the lower triangle of the variance-covariance matrix (" <code>lower.tri</code> ")?
<code>row.names, optional</code>	Ignored: necessary for the <code>as.data.frame</code> method.
<code>...</code>	Ignored for the <code>as.data.frame</code> method; passed to other <code>print()</code> methods for the <code>print()</code> method.
<code>comp</code>	a <b>character</b> vector, specifying the components to be printed; simply passed to <code>formatVC()</code> .
<code>formatter</code>	a <b>function</b> for formatting the numbers; simply passed to <code>formatVC()</code> .

**Details**

The `print` method for `VarCorr.merMod` objects has optional arguments `digits` (specify digits of precision for printing) and `comp`: the latter is a character vector with any combination of "`Variance`" and "`Std.Dev.`", to specify whether variances, standard deviations, or both should be printed.



**Value**

An object of class `VarCorr.merMod`. The internal structure of the object is a list of matrices, one for each random effects grouping term. For each grouping term, the standard deviations and correlation matrices for each grouping term are stored as attributes `"stddev"` and `"correlation"`, respectively, of the variance-covariance matrix, and the residual standard deviation is stored as attribute `"sc"` (for `glmer` fits, this attribute stores the scale parameter of the model).

The `as.data.frame` method produces a combined data frame with one row for each variance or covariance parameter (and a row for the residual error term where applicable) and the following columns:

**grp** grouping factor  
**var1** first variable  
**var2** second variable (NA for variance parameters)  
**vcov** variances or covariances  
**sdcor** standard deviations or correlations

**Author(s)**

This is modeled after `VarCorr` from package `nlme`, by Jose Pinheiro and Douglas Bates.

**See Also**

[lmer](#), [nlmer](#)

**Examples**

```
data(Orthodont, package="nlme")
fm1 <- lmer(distance ~ age + (age|Subject), data = Orthodont)
(vcov <- VarCorr(fm1)) ## default print method: standard dev and corr
## both variance and std.dev.
print(vcov, comp=c("Variance", "Std.Dev."), digits=2)
## variance only
print(vcov, comp=c("Variance"))
as.data.frame(vcov)
as.data.frame(vcov, order="lower.tri")
```

---

varianceProf

*Transform Profile to the variance scale*


---

**Description**

Transform a mixed-effects profile, i.e. conceptually, `x <- profile(lmer(...), ...)` from standard deviation to the variance scale.

**Usage**

```
varianceProf(x, ranef = TRUE)
```

**Arguments**

<code>x</code>	a mixed-effects model profile.
<code>ranef</code>	logical indicating if all sigmas should be transformed, see <a href="#">logProf</a> .

**Value**

a transformed mixed-effects model profile

**See Also**

[profile](#) and methods, notably, [logProf](#) for log transformation of the sigmas; also for nice examples including graphics.

---

vccov

---

*Convert between representations of (co-)variance structures*


---

**Description**

Convert between representations of (co-)variance structures (EXPERIMENTAL). See source code for details.

**Usage**

```
mlist2vec(L)
vec2mlist(v, n = NULL, symm = TRUE)
vec2STlist(v, n = NULL)
sdcov2cov(m)
cov2sdcov(V)
Vv_to_Cv(v, n = NULL, s = 1)
Sv_to_Cv(v, n = NULL, s = 1)
Cv_to_Vv(v, n = NULL, s = 1)
Cv_to_Sv(v, n = NULL, s = 1)
```

**Arguments**

<code>L</code>	List of symmetric, upper-triangular, or lower-triangular square matrices.
<code>v</code>	Concatenated vector containing the elements of the lower-triangle (including the diagonal) of a symmetric or triangular matrix.
<code>n</code>	Number of rows (and columns) of the resulting matrix.
<code>symm</code>	Return symmetric matrix if TRUE or lower-triangular if FALSE.
<code>m</code>	Standard deviation-correlation matrix.
<code>V</code>	Covariance matrix.
<code>s</code>	Scale parameter.

## Details

- `m1ist2vec` Convert list of matrices to concatenated vector of lower triangles with an attribute that gives the dimension of each matrix in the original list. This attribute may be used to reconstruct the matrices. Returns a concatenation of the elements in one triangle of each matrix. An attribute "c1en" gives the dimension of each matrix.
- `vec2m1ist` Convert concatenated vector to list of matrices (lower triangle or symmetric). These matrices could represent Cholesky factors, covariance matrices, or correlation matrices (with standard deviations on the diagonal).
- `vec2ST1ist` Convert concatenated vector to list of ST matrices.
- `sdcor2cov` Standard deviation-correlation matrix to covariance matrix convert 'sdcor' format (std dev on diagonal, cor on off-diag) to and from variance-covariance matrix.
- `cov2sdcor` Covariance matrix to standard deviation-correlation matrix (i.e. standard deviations on the diagonal and correlations off the diagonal).
- `Vv_to_Cv` Variance-covariance to relative covariance factor. Returns a vector of elements from the lower triangle of a relative covariance factor.
- `Sv_to_Cv` Standard-deviation-correlation to relative covariance factor. Returns a vector of elements from the lower triangle of a relative covariance factor.
- `Cv_to_Vv` Relative covariance factor to variance-covariance. From unscaled Cholesky vector to (possibly scaled) variance-covariance vector. Returns a vector of elements from the lower triangle of a variance-covariance matrix.
- `Cv_to_Sv` Relative covariance factor to standard-deviation-correlation. From unscaled Chol to sd-cor vector. Returns a vector of elements from the lower triangle of a standard-deviation-correlation matrix.

## Value

(Co-)variance structure

## Examples

```
vec2m1ist(1:6)
m1ist2vec(vec2m1ist(1:6)) # approximate inverse
```

---

VerbAgg

*Verbal Aggression item responses*

---

## Description

These are the item responses to a questionnaire on verbal aggression. These data are used throughout De Boeck and Wilson, *Explanatory Item Response Models* (Springer, 2004) to illustrate various forms of item response models.

**Format**

A data frame with 7584 observations on the following 13 variables.

Anger the subject's Trait Anger score as measured on the State-Trait Anger Expression Inventory (STAXI)

Gender the subject's gender - a factor with levels M and F

item the item on the questionnaire, as a factor

resp the subject's response to the item - an ordered factor with levels no < perhaps < yes

id the subject identifier, as a factor

btype behavior type - a factor with levels curse, scold and shout

situ situation type - a factor with levels other and self indicating other-to-blame and self-to-blame

mode behavior mode - a factor with levels want and do

r2 dichotomous version of the response - a factor with levels N and Y

**Source**

<http://bear.soe.berkeley.edu/EIRM/>

**References**

De Boeck and Wilson (2004), *Explanatory Item Response Models*, Springer.

**Examples**

```
str(VerbAgg)
## Show how r2 := h(resp) is defined:
with(VerbAgg, stopifnot( identical(r2, {
  r <- factor(resp, ordered=FALSE); levels(r) <- c("N","Y","Y"); r})))

xtabs(~ item + resp, VerbAgg)
xtabs(~ btype + resp, VerbAgg)
round(100 * ftable(prop.table(xtabs(~ situ + mode + resp, VerbAgg), 1:2), 1))
person <- unique(subset(VerbAgg, select = c(id, Gender, Anger)))
require(lattice)
densityplot(~ Anger, person, groups = Gender, auto.key = list(columns = 2),
  xlab = "Trait Anger score (STAXI)")

if(lme4:::testLevel() >= 3) { ## takes about 15 sec
print(fmVA <- glmer(r2 ~ (Anger + Gender + btype + situ)^2 +
  (1|id) + (1|item), family = binomial, data =
  VerbAgg), corr=FALSE)
}

## much faster but less accurate
print(fmVA0 <- glmer(r2 ~ (Anger + Gender + btype + situ)^2 +
  (1|id) + (1|item), family = binomial, data =
  VerbAgg, nAGQ=0L), corr=FALSE)
```

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