Package ‘skewlmm’

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Title Scale Mixture of Skew-Normal Linear Mixed Models
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Description It fits scale mixture of skew-normal linear mixed models using an expectation–maximization (EM) type algorithm, including some possibilities for modeling the within-subject dependence. Details can be found in Schumacher, Matos and Lachos (2020) <arXiv:2002.01040>.
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errorVar

Description

It returns a variance matrix associated with the error term at time times. Can be applied to a smsn.lmm object or to a specific dependence structure with chosen parameter values.

Usage

```r
errorVar(times, object = NULL, sigma2 = NULL, depStruct = NULL, phi = NULL)
```

Arguments

times A vector containing the times for which the matrix should be calculated.
object A smsn.lmm object for which the variance should be extracted.
sigma2 Common variance parameter, such that $\Sigma = \sigma^2 \cdot R$. Only evaluated if object is.null(object).
depStruct Dependence structure. "CI" for condicional independence, "ARp" for AR(p) – p is length(phi) –, "CS" for compound symmetry, "DEC" for DEC, and "CAR1" for continuous-time AR(1). Only evaluated if object is.null(object).
phi Parameter vector indexing the dependence structure. Only evaluated if object is.null(object).

Value

Matrix of dimension length(times).

Author(s)

Fernanda L. Schumacher, Larissa A. Matos and Victor H. Lachos

References

fitted.SMN

See Also

smsn.lmm, summary.SMN

Examples

```r
fm1 <- smsn.lmm(distance ~ age + Sex, data = nlme::Orthodont, groupVar="Subject")
errorVar(times=1:4,fm1)
#
errorVar(times=1:5,sigma2 = 1, depStruct = "ARp",phi = .5)
errorVar(times=1:5,sigma2 = 1, depStruct = "DEC",phi = c(.5,.8))
```

fitted.SMN

Extract smn.lmm fitted values

Description

The fitted values are obtained by adding together the population fitted values (based only on the fixed effects estimates) and the estimated contributions of the random effects to the fitted values at grouping levels.

Usage

```r
## S3 method for class 'SMN'
fitted(object, ...)
```

Arguments

- **object**: an object inheriting from class SMN, representing a fitted scale mixture normal linear mixed model.
- **...**: Additional arguments.

Value

Vector of fitted values with length equal to nrow(data).

Author(s)

Fernanda L. Schumacher, Larissa A. Matos and Victor H. Lachos

References


See Also

snn.lmm, predict.SMSN

Examples

```r
fm1 <- snn.lmm(distance ~ age + Sex, data = nlme::Orthodont, groupVar="Subject")
fitted(fm1)
```

Description

The fitted values are obtained by adding together the population fitted values (based only on the fixed effects estimates) and the estimated contributions of the random effects to the fitted values at grouping levels.

Usage

```r
## S3 method for class 'tSN'
fitted(object, ...)
```

Arguments

- `object`: an object inheriting from class SMSN, representing a fitted scale mixture skew-normal linear mixed model.
- `...`: Additional arguments.

Value

Vector of fitted values with length equal to nrow(data).

Author(s)

Fernanda L. Schumacher, Larissa A. Matos and Victor H. Lachos

References


See Also

snn.lmm, predict.SMSN
Examples

```r
fm1 <- sdsn.lmm(distance ~ age + Sex, data = nlme::Orthodont, groupVar="Subject",tol = .0001)
fitted(fm1)
```

### Description

It performs a likelihood-ratio test for two nested SMSN-LMM or SMN-LMM.

### Usage

```r
lr.test(obj1, obj2, level=0.05, quiet=FALSE)
```

### Arguments

- `obj1, obj2`: `sdsn.lmm` or `smn.lmm` objects containing the fitted models to be tested.
- `level`: The significance level that should be used. If `quiet=TRUE`, this is ignored.
- `quiet`: A logical value indicating if the result message should be suppressed. Default is `FALSE`.

### Value

- `statistic`: The test statistic value.
- `p.value`: The p-value from the test.
- `df`: The degrees of freedom used on the test.

### Author(s)

Fernanda L. Schumacher, Larissa A. Matos and Victor H. Lachos

### References


### See Also

`sdsn.lmm`, `smn.lmm`

### Examples

```r
fm1 <- sdsn.lmm(nlme::Orthodont, formFixed=distance ~ age+Sex, groupVar="Subject")
fitted(fm1)
mf2 <- sdsn.lmm(nlme::Orthodont, formFixed=distance ~ age+Sex, groupVar="Subject", tol=.0001)
lr.test(fm1,fm2)
```
**predict.SMN**  
*Prediction of future observations from an smn.lmm object*

**Description**

Predicted values are obtained through conditional expectation. For details, see Schumacher, Matos and Lachos (2020).

**Usage**

```r
## S3 method for class 'SMN'
predict(object, newData,...)
```

**Arguments**

- `object`  
an object inheriting from class `SMN`, representing a fitted scale mixture normal linear mixed model.
- `newData`  
a data frame for which response variable should be predicted, including covariates, groupVar and possibly timeVar.
- `...`  
Additional arguments.

**Value**

A data frame with covariates, groupVar and ypred, where ypred contains the predicted values from the response variable.

**Author(s)**

Fernanda L. Schumacher, Larissa A. Matos and Victor H. Lachos

**References**


**See Also**

- `smn.lmm`
- `fitted.SMN`

**Examples**

```r
dat1 <- nlme::Orthodont
fm1 <- smn.lmm(distance ~ age + Sex, data = subset(dat1,age<14), groupVar="Subject")
predict(fm1,subset(dat1,age==14))
```
Description

Predicted values are obtained through conditional expectation. For details, see Schumacher, Matos and Lachos (2020).

Usage

## S3 method for class 'SMSN'
predict(object, newData,...)

Arguments

- `object`: an object inheriting from class SMSN, representing a fitted scale mixture skew-normal linear mixed model.
- `newData`: a data frame for which response variable should be predicted, including covariates, groupVar and possibly timeVar.
- `...`: Additional arguments.

Value

A data frame with covariates, groupVar and ypred, where ypred contains the predicted values from the response variable.

Author(s)

Fernanda L. Schumacher, Larissa A. Matos and Victor H. Lachos

References


See Also

`smsn.lmm`, `fitted.SMSN`

Examples

dat1 <- nlme::Orthodont
fm1 <- smsn.lmm(distance ~ age + Sex, data = subset(dat1, age<14), groupVar="Subject")
predict(fm1, subset(dat1, age==14))
Print a `smn.lmm` object

Description

Print a `smn.lmm` object.

Usage

```r
## S3 method for class 'SMN'
print(x, ...)
```

Arguments

- `x`: an object inheriting from class `SMN`, representing a fitted scale mixture normal linear mixed model.
- `...`: Additional print arguments.

Author(s)

Fernanda L. Schumacher, Larissa A. Matos and Victor H. Lachos

References


See Also

- `smn.lmm`, `summary.SMN`

Examples

```r
fm1 <- smn.lmm(distance ~ age + Sex, data = nlme::Orthodont, groupVar="Subject")
fm1
```
Print a smsn.lmm object

Description

Print a smsn.lmm object.

Usage

```r
## S3 method for class 'SMSN'
print(x, ...)  
```

Arguments

- `x`: an object inheriting from class SMSN, representing a fitted scale mixture skew-normal linear mixed model.
- `...`: Additional print arguments.

Author(s)

Fernanda L. Schumacher, Larissa A. Matos and Victor H. Lachos

References


See Also

`smsn.lmm`, `summary.SMSN`

Examples

```r
fm1 <- smsn.lmm(distance ~ age + Sex, data = nlme::Orthodont, groupVar="Subject")
fm1
```
Generate data from SMSN-LMM

Description

It creates a simulated data set from SMSN-LMM (or from SMN-LMM, if \( \lambda = 0 \)) with several possible dependence structures, for one subject.

Usage

```r
rsmsn.lmm(time1, x1, z1, sigma2, D1, beta, lambda, depStruct = "CI",
          phi = NULL, distr = "sn", nu = NULL)
```

Arguments

- `time1`: Vector containing times that should be used in data generation.
- `x1`: Design matrix for fixed effects.
- `z1`: Design matrix for random effects.
- `sigma2`: Common variance parameter, such that \( \Sigma = \sigma^2 R \).
- `D1`: Variance matrix for random effects.
- `beta`: Vector of fixed effects parameter.
- `lambda`: Skewness parameter of random effects.
- `depStruct`: Dependence structure. "CI" for conditional independence, "ARp" for AR(p) – \( p = \) length(phi) –, "CS" for compound symmetry, "DEC" for DEC, and "CAR1" for continuous-time AR(1).
- `phi`: Parameter vector indexing the dependence structure.
- `distr`: Distribution that should be used. "sn" for skew-normal, "st" for skew-t, "ss" for skew-slash, and "scn" for skew-contaminated normal.
- `nu`: Parameter vector indexing distr. Should be NULL for "sn", be a vector of length 1 for "st" and "ss", and of length 2 for "scn".

Value

A data frame containing time, the generated response variable (\( y \)), and possible covariates.

Author(s)

Fernanda L. Schumacher, Larissa A. Matos and Victor H. Lachos

References


See Also

**smsn.lmm**

Examples

# generating a sample for 1 individual at 5 times
nj1<-5
rsmsn.lmm(1:nj1,cbind(1,1:nj1),rep(1,nj1),sigma2=.25,
D1=diag(1),beta = c(1,2),lambda = 2,depStruct = "ARp",phi=.5,
distr="st",nu=5)

# generating a sample for m=20 individuals at 5 times
library(dplyr)
library(purrr)
library(ggplot2)
nj1<-5
m<-50
gendatList<- map(rep(nj1,m), function(nj) rsmsn.lmm(1:nj,cbind(1,1:nj),rep(1,nj),sigma2=.25,
D1=.5*diag(1),beta = c(1,2),lambda = 2,depStruct = "ARp",phi=.5))
gendat<- bind_rows(gendatList,.id="ind")
ggplot(gendat,aes(x=x,y=y,group=ind)) + geom_line() +
stat_summary(aes(group = 1),geom = "line", fun.y = mean, col="blue",size=2)

#
fm1 <- smsn.lmm(y ~ x, data = gendat, groupVar="ind", depStruct="ARp", pAR=1)
summary(fm1)

---

**smn.lmm**

ML estimation of scale mixture of normal linear mixed models

Description

It fits a scale mixture of normal linear mixed model with possible within-subject dependence structure, using an EM-type algorithm. It provides estimates and standard errors of parameters.

Usage

```r
smn.lmm(data, formFixed, groupVar, formRandom = ~1, depStruct = "CI",

timeVar = NULL, distr = "norm", pAR = 1, luDEC = 10,
tol = 1e-06, max.iter = 200, calc.se = TRUE, calc.bi = TRUE, lb = NULL,
lu = NULL, initialValues = list(beta = NULL, sigma2 = NULL,
D = NULL, phi = NULL, nu = NULL), quiet = FALSE)
```

Arguments

- **data**: A data frame containing the variables named in `formFixed`, `formRandom`, `groupVar`, and `timeVar`.
- **formFixed**: A two-sided linear formula object describing the fixed effects part of the model, with the response on the left of a `~` operator and the covariates, separated by `+` operators, on the right.
groupVar A character containing the name of the variable which represents the subjects or groups in data.

formRandom A one-sided linear formula object describing the random effects part of the model, with the covariates, separated by + operators, on the right of a ~ operator. By default, a model with random intercept is considered.

depStruct A character indicating which dependence structure should be used. "CI" for conditional independence, "ARp" for AR(p) – p is length(phi) –, "CS" for compound symmetry, "DEC" for DEC, and "CAR1" for continuous-time AR(1).

timeVar A character containing the name of the variable which represents the time in data. Meaningless if depStruct="CI" or depStruct="CS". For other structures, if is.null(timeVar) the observations are considered equally spaced and ordered. If depStruct="ARp", timeVar must the an index, preferably starting at 1.

distr A character indicating which distribution should be used. "norm" for normal, "t" for t, "sl" for slash, and "cn" for contaminated normal.

pAR If depStruct="ARp", pAR indicates the order of the autoregressive process that should be used. Otherwise, it is meaningless.

luDEC Optional. Upper limit for estimating the "damping" parameter for DEC covariance. If luDEC<=1, only attenuation of the exponential decay can be obtained.

tol Tolerance for the convergence criterion. Default=1e-6.

max.iter Maximum number of iterations for the EM algorithm. Default=200.

calc.se A logical value indicating if standard errors should be calculated.

calc.bi A logical value indicating if random effects should be estimated.

lb Optional. Bottom limit for estimating nu.

lu Optional. Upper limit for estimating nu.

initialValues Optional. A named list containing initial parameter values, with at most the following elements: beta, sigma2, d, phi, nu.

quiet A logical value indicating if the iteration message should be suppressed. Useful when calling the function in R Markdown.

Details

It fits the model $Y_i = X_i \beta + Z_i b_i + \epsilon_i$, for $i = 1, \ldots, n$, where $Y_i$ is a vector with $n_i$ observed continuous responses, $b_i \ SIMN(0, D; H)$ and $\epsilon_i \ SIMN(0, \Sigma_i; H)$, indexed by the same mixing distribution.

For details see Schumacher, Matos & Lachos (2020+).

Value

An object of class "SMN" representing the SMN-LMM fit. Generic functions such as print and summary have methods to show the results of the fit. The functions fitted and ranef can be used to extract some of its components.

Specifically, the following components are returned:
theta
iter
estimates
random.effects
std.error
loglik
elapsedTime
error
call
criteria
data
formula
depStruct
distr
N
n
groupVar
timeVar
fitted

Author(s)
Fernanda L. Schumacher, Larissa A. Matos and Victor H. Lachos

References

See Also
print.SMN, summary.SMN, predict.SMN, smsn.lmm

Examples
#simple example
dat1 <- as.data.frame(nlme::Orthodont)
fm1 <- smn.lmm(dat1,formFixed=distance ~ age,groupVar="Subject",max.iter = 30)
fml
#fitting for several distributions / dependence structures
fm1 <- smn.lmm(dat1,formFixed=distance ~ age+Sex,groupVar="Subject")


```r
fm2 <- smn.lmm(dat1, formFixed=distance ~ age+Sex, groupVar="Subject", distr="t")
fm3 <- smn.lmm(dat1, formFixed=distance ~ age+Sex, groupVar="Subject", distr="st")
fm4 <- smn.lmm(dat1, formFixed=distance ~ age+Sex, groupVar="Subject", depStruct="ARp", pAR=1)
rbind(fm1$criteria, fm2$criteria, fm3$criteria, fm4$criteria)
summary(fm3)
```

**smn.lmm**

*ML estimation of scale mixture of skew-normal linear mixed models*

**Description**

It fits a scale mixture of skew-normal linear mixed model with possible within-subject dependence structure, using an EM-type algorithm. It provides estimates and standard errors of parameters.

**Usage**

```r
smn.lmm(data, formFixed, groupVar, formRandom = ~1, depStruct = "CI",
        timeVar = NULL, distr = "sn", pAR = 1, luDEC = 10,
        tol = 1e-06, max.iter = 200, calc.se = TRUE, calc.bi = TRUE, lb = NULL,
        lu = NULL, initialValues = list(beta = NULL, sigma2 = NULL,
          D = NULL, lambda = NULL, phi = NULL, nu = NULL), quiet = FALSE)
```

**Arguments**

- `data` A data frame containing the variables named in `formFixed`, `formRandom`, `groupVar`, and `timeVar`.
- `formFixed` A two-sided linear formula object describing the fixed effects part of the model, with the response on the left of a `~` operator and the covariates, separated by `+` operators, on the right.
- `groupVar` A character containing the name of the variable which represents the subjects or groups in `data`.
- `formRandom` A one-sided linear formula object describing the random effects part of the model, with the covariates, separated by `+` operators, on the right of a `~` operator. By default, a model with random intercept is considered.
- `depStruct` A character indicating which dependence structure should be used. "CI" for conditional independence, "ARp" for AR(p) – p is length(phi) –, "CS" for compound symmetry, "DEC" for DEC, and "CAR1" for continuous-time AR(1).
- `timeVar` A character containing the name of the variable which represents the time in `data`. Meaningless if `depStruct="CI"` or `depStruct="CS"`. For other structures, if `is.null(timeVar)` the observations are considered equally spaced and ordered. If `depStruct="ARp"`, timeVar must the an index, preferably starting at 1.
- `distr` A character indicating which distribution should be used. "sn" for skew-normal, "st" for skew-t, "ss" for skew-slash, and "scn" for skew-contaminated normal.
pAR: If depStruct="ARp", pAR indicates the order of the autoregressive process that should be used. Otherwise, it is meaningless.

luDEC: Optional. Upper limit for estimating the "damping" parameter for DEC covariance. If luDEC=1, only attenuation of the exponential decay can be obtained.

tol: Tolerance for the convergence criterion. Default=1e-6.

max.iter: Maximum number of iterations for the EM algorithm. Default=200.

calc.se: A logical value indicating if standard errors should be calculated.

calc.bi: A logical value indicating if random effects should be estimated.


lu: Optional. Upper limit for estimating nu.

initialValues: Optional. A named list containing initial parameter values, with at most the following elements: beta, sigma2, D, lambda, phi, nu.

quiet: A logical value indicating if the iteration message should be suppressed. Useful when calling the function in R Markdown.

Details

It fits the model \( Y_i = X_i\beta + Z_i b_i + \epsilon_i \), for \( i = 1, \ldots, n \), where \( Y_i \) is a vector with \( n_i \) observed continuous responses, \( b_i \sim SMSN(c\Delta, D, \lambda; H) \) and \( \epsilon_i \sim SMN(0, \Sigma_i; H) \), indexed by the same mixing distribution.

For details see Schumacher, Matos & Lachos (2020+).

Value

An object of class "SMSN" representing the SMSN-LMM fit. Generic functions such as print and summary have methods to show the results of the fit. The functions fitted and ranef can be used to extract some of its components.

Specifically, the following components are returned:

- theta: Named vector with parameter estimates.
- iter: Number of iterations runned.
- estimates: A named list containing parameter estimates.
- random.effects: Estimated random effects.
- std.error: A vector with standard errors.
- loglik: Value of the log-likelihood at last iteration.
- elapsedTime: Time elapsed in processing, in seconds.
- error: Convergence criterion at last iteration.
- call: The smsg.lmm call that produced the object.
- criteria: A list with AIC and BIC criterion.
- data: The data frame used on smsg.lmm call.
- formula: A list containing the formulas used on smsg.lmm call.
- depStruct: A character indicating which dependence structure was used.
distr  A character indicating which distribution was used.
N     The number of observations used.
n     The number of individuals/groups used.
groupVar  A character indicating the name of the grouping variable.
timeVar  A character indicating the name of the time variable, if any.
fitted  A vector of fitted values, if calc.bi=TRUE.

Author(s)
Fernanda L. Schumacher, Larissa A. Matos and Victor H. Lachos

References

See Also
print.SMSN, summary.SMSN, predict.SMSN

Examples
# simple example
dat1 <- as.data.frame(nlme::Orthodont)
fm1 <- smsn.lmm(dat1,formFixed=distance ~ age,groupVar="Subject",max.iter = 30)
 fm1

# fitting for several distributions / dependence structures
fm1 <- smsn.lmm(dat1,formFixed=distance ~ age+Sex,groupVar="Subject")
fm2 <- smsn.lmm(dat1,formFixed=distance ~ age+Sex,groupVar="Subject", distr="st")
fm3 <- smsn.lmm(dat1,formFixed=distance ~ age+Sex,groupVar="Subject", distr="ss")
fm4 <- smsn.lmm(dat1,formFixed=distance ~ age+Sex,groupVar="Subject", depStruct="ARp",pAR=1)
 rbind(fm1$criteria,fm2$criteria,fm3$criteria,fm4$criteria)
summary(fm3)

summary.SMN  Summary of a smn.lmm object

Description
summary method for class "SMN".
Usage

```r
## S3 method for class 'SMN'
summary(object, confint.level = 0.95, ...)
```

Arguments

- `object`: an object inheriting from class `SMN`, representing a fitted scale mixture normal linear mixed model.
- `confint.level`: Level of the approximate confidence intervals presented. Default=0.95.
- `...`: Additional arguments.

Value

- `varRandom`: estimated variance matrix from random effects (\(D\)).
- `varFixed`: parameter estimates of variance from random errors (\(\Sigma\)). For recovering the error variance matrix use `errorVar` function.
- `tableFixed`: estimated fixed effects, their standard errors and approximated confidence intervals.
- `criteria`: Log-likelihood value from MLE, AIC and BIC criteria.

Author(s)

Fernanda L. Schumacher, Larissa A. Matos and Victor H. Lachos

References


See Also

- `smn.lmm`, `errorVar`

Examples

```r
fm1 <- smn.lmm(distance ~ age + Sex, data = nlme::Orthodont, groupVar="Subject")
summary(fm1)
```
Summary of a "SMSN" object

Description

summary method for class "SMSN".

Usage

## S3 method for class 'SMSN'
summary(object, confint.level = 0.95, ...)

Arguments

object an object inheriting from class SMSN, representing a fitted scale mixture skew-normal linear mixed model.

confint.level Level of the approximate confidence intervals presented. Default=0.95.

... Additional arguments.

Value

varRandom estimated variance matrix from random effects (D).

varFixed parameter estimates of variance from random errors (Σ). For recovering the error variance matrix use errorVar function.

tableFixed estimated fixed effects, their standard errors and approximated confidence intervals.

criteria Log-likelihood value from MLE, AIC and BIC criteria.

Author(s)

Fernanda L. Schumacher, Larissa A. Matos and Victor H. Lachos

References


See Also

smsn.lmm, errorVar

Examples

fm1 <- smsn.lmm(distance ~ age + Sex, data = nlme::Orthodont, groupVar="Subject", tol=.0001)
summary(fm1)
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