Package 'brokenstick'

July 22, 2025

Type Package

Title Broken Stick Model for Irregular Longitudinal Data

Version 2.6.0

Description Data on multiple individuals through time are often sampled at times that differ between persons. Irregular observation times can severely complicate the statistical analysis of the data. The broken stick model approximates each subject's trajectory by one or more connected line segments. The times at which segments connect (breakpoints) are identical for all subjects and under control of the user. A well-fitting broken stick model effectively transforms individual measurements made at irregular times into regular trajectories with common observation times. Specification of the model requires three variables: time, measurement and subject. The model is a special case of the linear mixed model, with time as a linear B-spline and subject as the grouping factor. The main assumptions are: subjects are exchangeable, trajectories between consecutive breakpoints are straight, random effects follow a multivariate normal distribution, and unobserved data are missing at random. The package contains functions for fitting the broken stick model to data, for predicting curves in new data and for plotting broken stick estimates. The package supports two optimization methods, and includes options to structure the variance-covariance matrix of the random effects. The analyst may use the software to smooth growth curves by a series of connected straight lines, to align irregularly observed curves to a common time grid, to create synthetic curves at a user-specified set of breakpoints, to estimate the time-to-time correlation matrix and to predict future observations. See <doi:10.18637/jss.v106.i07> for additional documentation on background, methodology and applications.

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URL doi:10.18637/jss.v106.i07, https://growthcharts.org/brokenstick/

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Contents

brokenstick-package **brokenstick***: A package for irregular longitudinal data.*

Description

The broken stick model describes a set of individual curves by a linear mixed model using second-order linear B-splines. The main use of the model is to align irregularly observed data to a user-specified grid of break ages.

Details

The **brokenstick** package contains functions for fitting a broken stick model to data, for predicting broken stick curves for new data, and for plotting the results.

brokenstick functions

The main functions are:

`brokenstick()`	Fit a broken stick model to irregular data
`plot()`	Plot observed and fitted trajectories by group
`predict()`	Obtain predictions on new data
`summary()`	Extract object summaries

The following functions are user-oriented helpers:

`coef()`	Extract estimated parameters
`fitted()`	Calculate fitted values
`get_knots()`	Obtain the knots from a broken stick model
`get_omega()`	Extract variance-covariance of random effects
`get_r2()`	Obtain proportion of explained variance
`model.frame()`	Extract model frame
`model.matrix()`	Extract design matrix
`residuals()`	Extract residuals from broken stick model

The following functions perform calculations:

`set_control()`	Set controls to steer calculations
`control_kr()`	Set controls for the `kr` method

Note

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Author(s)

Maintainer: Stef van Buuren <stef.vanbuuren@tno.nl>

References

van Buuren, S. (2023). Broken Stick Model for Irregular Longitudinal Data. *Journal of Statistical Software*, 106(7), 1–51. doi:10.18637/jss.v106.i07

van Buuren, S. (2018). *Flexible Imputation of Missing Data. Second Edition*. Chapman & Hall/CRC. Chapter 11. https://stefvanbuuren.name/fimd/sec-rastering.html#sec:brokenstick #' @keywords internal

See Also

brokenstick, EB, predict.brokenstick

---

brokenstick *Fit a* brokenstick *model to irregular data*

Description

The brokenstick() function fits an irregularly observed series of measurements onto a user-specified grid of points (knots). The model codes the grid by a series of linear B-splines. Each modelled trajectory consists of straight lines that join at the chosen knots and look like a broken stick. Differences between observations are expressed by a random effect per knot.

Usage

```
brokenstick(
  formula,
  data,
  knots = NULL,
  boundary = NULL,
  k = 5L,
  degree = 1L,
  method = c("kr", "lmer"),
  control = set_control(method = method, ...),
  na.action = na.exclude,
  light = FALSE,
  hide = c("right", "left", "boundary", "internal", "none"),
  ...
)
```

Arguments

formula	A formula specifying the outcome, the predictor and the group variable in data. The generic shape is formula = y ~ x | group. The left-hand side is the outcome, the right-hand side the predictor, and the name of the grouping variable occurs after the | sign. Formula treatment is non-standard: 1) y and x should be numeric, 2) only one variable is allowed in each model term (additional variables will be ignored).
data	A data frame or matrix containing the outcome (numeric), predictor (numeric) and group (numeric, factor, character) variable.
knots	Optional, but recommended. Numerical vector with the locations of the internal knots to be placed on the values of the predictor. The function sorts the internal knots in increasing order.
boundary	Optional, but recommended. Numerical vector of length 2 with the left and right boundary knot. The boundary setting is passed to splines::bs() as the Boundary.knots argument. If not specified, the function determines the boundary knots as range(x). When specified, the boundary range is internally expanded to include at least range(knots).
k	Optional, a convenience parameter for the number of internal knots. If specified, then k internal knots are placed at equidense quantiles of the predictor. For example, specifying k = 1 puts a knot at the 50th quantile (median), setting k = 3 puts knots at the 25th, 50th and 75th quantiles, and so on. If the user specifies both k and knots arguments then knots takes precedence. The default is k = 5, so if the user does not specify any of knots, boundary or k, then the knots will be at the 16th, 33th, 50th, 66th and 84th quantile of the predictor.
degree	the degree of the spline. The broken stick model requires linear splines, so the default is degree = 1. Setting degree = 0 yields (crisp) dummy coding, and one column less than for degree = 1. The brokenstick package supports only degree = 0 and degree = 1.
method	Estimation method. Either "kr" (for the Kasim-Raudenbush sampler) or "lmer" (for lme4::lmer()). Version 1.1.1.9000 changed the default to method = "kr".
control	List of control options returned by set_control() used to set algorithmic details. A list with parameters. When not specified, the functions sets to defaults for method "kr" by control_kr(), and for method "lmer" by lme4::lmerControl(). For ease of use, the user may set individual options to "kr" (e.g. niter = 500) via the ... arguments.
na.action	A function that indicates what lme4::lmer() should so when the data contain NAs. Default set to na.exclude. Only used by method "lmer".
light	Should the returned object be lighter? If light = TRUE the returned object will contain only the model settings and parameter estimates and not store the data, imp and mod elements. The light object can be used to predict broken stick estimates for new data, but does not disclose the training data and is very small (often <20 Kb).
hide	Should output for knots be hidden in get, print, summary and plot functions? Can be "left", "right", "boundary", "internal" or "none". The default is "right".
...	Forwards arguments to control_kr().

Details

The choice between `method = "kr"` and `method = "lmer"` depends on the size of the data and the complexity of the model. In general, setting `method = "lmer"` can require substantial calculation time for more complex models (say > 8 internal knots) and may not converge. Method `"kr"` is less sensitive to model complexity and small samples, and has the added benefit that the variance-covariance matrix of the random effects can be constrained through the `cormodel` argument. On the other hand, `"lmer"` is the better-researched method, and is more efficient for simpler models and datasets with many rows.

The default algorithm since version 2.0 is the Bayesian Kasim-Raudenbush sampler (`method = "kr"`). The variance-covariance matrix of the broken stick estimates absorbs the relations over time. The `"kr"` method allows enforcing a simple structure on this variance-covariance matrix. Currently, there are three such correlation models: `"none"` (default), `"argyle"` and `"cole"`. Specify the `seed` argument for reproducibility. See `control_kr()` for more details.

The alternative `method = "lmer"` fits the broken stick model by `lme4::lmer()`. With this method, the variance-covariance matrix can only be unstructured. This estimate may be unstable if the number of children is small relative to the number of specified knots. The default setting in `lme4::lmerControl()` is `check.nobs.vs.nRE= "stop"`. The `[set_control()]` function changes this to `check.nobs.vs.nRE= "warning"` by default, since otherwise many broken stick models would not run at all. The method throws warnings that estimates are not stable. It can be time for models with many internal knots. Despite the warnings, the results often look reasonable.

Diagnostics with **coda** and **lme4**: The function returns an object of class `brokenstick`. For `method = "kr"` the list component named `"mod"` contains a list of `mcmc` objects that can be further analysed with `coda::acfplot()`, `coda::autocorr()`, `coda::crosscorr()`, `coda::cumuplot()`, `coda::densplot()`, `coda::effectiveSize()`, `coda::geweke.plot()`, `coda::raftery.diag()`, `coda::traceplot()` and the usual `plot()` and `summary()` functions. For `method = "lmer"` the list component named `"mod"` contains an object of class lme4::merMod. These model objects are omitted in light `brokenstick` objects.

Value

A object of class `brokenstick`.

Note

Note that automatic knot specification is data-dependent, and may not reproduce on other data. Likewise, knots specified via `k` are data-dependent and do not transfer to other data sets. Fixing the model requires specifying both `knots` and `boundary`.

Examples

```
data <- smocc_200[1:1198, ]

# using kr method, default
f1 <- brokenstick(hgt_z ~ age | id, data, knots = 0:2, seed = 123)
plot(f1, data, n_plot = 9)

# study sampling behaviour of the sigma2 parameter with coda
library("coda")
```

```
plot(f1$mod$sigma2)
acfplot(f1$mod$sigma2)

# using lmer method
f2 <- brokenstick(hgt_z ~ age | id, data, knots = 0:2, method = "lmer")
plot(f2, data, n_plot = 9)

# drill down into merMod object with standard diagnostics in lme4
summary(f2$mod)
plot(f2$mod)

# a model with more knots
knots <- round(c(0, 1, 2, 3, 6, 9, 12, 15, 18, 24, 36) / 12, 4)

# method kr takes about 2 seconds
f3 <- brokenstick(hgt_z ~ age | id, data, knots, seed = 222)
plot(f3, data, n_plot = 9)

# method lmer takes about 40 seconds
f4 <- brokenstick(hgt_z ~ age | id, data, knots, method = "lmer")
plot(f4, data, n_plot = 9)
```

`brokenstick-class` *Class* `brokenstick`

Description

The main fitting function `brokenstick()` returns an object of class `brokenstick`. This object collects the fitted broken stick model.

Details

The package exports S3 methods for the `brokenstick` class for the following generic functions: `coef()`, `fitted()`, `model.frame()`, `model.matrix()`, `plot()`, `predict()`, `print()`, `residuals()` and `summary()`.

The package exports the following helper functions for `brokenstick` objects: `get_knots()`, `get_omega()` and `get_r2()`.

A `brokenstick` object is a list with the following named elements:

Elements

`call` Call that created the object

`names` A named list with three elements (`"x"`, `"y"`, `"g"`) providing the variable name for time, outcome and subject, respectively.

`internal` Numeric vector of with internal knots.

`boundary` Numeric vector of length 2 with the boundary knots.

`degree` The degree of the B-spline. See `splines::bs()`. Support only the values of 0 (step model) or 1 (broken stick model).

`method` String, either `"kr"` or `"lmer"`, identifying the fitting model.

`control` List of control options returned by `set_control()` used to set algorithmic details.

`beta` Numeric vector with fixed effect estimates.

`omega` Numeric matrix with variance-covariance estimates of the broken stick estimates.

`sigma2` Numeric scalar with the mean residual variance.

`sample` A numeric vector with descriptives of the training data.

`light` Should the returned object be lighter? If `light = TRUE` the returned object will contain only the model settings and parameter estimates and not store the `sigma2j`, `sample`, `data`, `imp` and `mod` elements. The light object can be used to predict broken stick estimates for new data, but does not disclose the training data and is small.

`hide` Should the output for boundary knots be hidden? Can be `"right"`, `"left"`, `"boundary"`, `"internal"` or `"none"`. The default is `"right"`.

`sigma2j` Numeric vector with estimates of the residual variance per group. Only used by method `"kr"`.

`data` The training data used to fit the model.

`imp` The imputations generated for the missing outcome data. Only for `method = "kr"`.

`mod` For `method = "kr"`: A named list with four components, each of class coda::mcmc. For `method = "lmer"`: An object of class lme4::merMod.

Author(s)

Stef van Buuren 2023

References

doi:10.18637/jss.v106.i07

`coef.brokenstick` *Extract Model Coefficients from brokenstick Object*

Description

Extract Model Coefficients from brokenstick Object

Usage

```
## S3 method for class 'brokenstick'
coef(
  object,
  complete = TRUE,
  ...,
  hide = c("right", "left", "boundary", "internal", "none")
)
```

Arguments

object	A brokenstick object
complete	for the default (used for lm, etc) and aov methods: logical indicating if the full coefficient vector should be returned also in case of an over-determined system where some coefficients will be set to NA, see also alias. Note that the default *differs* for lm() and aov() results.
...	other arguments.
hide	Should output for boundary knots be hidden in the print, summary and plot functions? Can be "right", "left", "boundary", "internal" or "none". If not specified, it is read from object$hide.

---

control_kr *Set controls for Kasim-Raudenbush sampler*

Description

Set controls for Kasim-Raudenbush sampler

Usage

```
control_kr(
  niter = 200L,
  nimp = 0L,
  start = 101L,
  thin = 1L,
  seed = NA_integer_,
  cormodel = c("none", "argyle", "cole"),
  ...
)
```

Arguments

niter	Integer. Number of samples from posterior. Default: 200.
nimp	Integer. Number of multiple imputations. Default: 0.
start	Integer. The iteration number of the first observation
thin	Integer. The thinning interval between consecutive observations
seed	Integer. Seed number for base::set.seed(). Use NA to bypass seed setting.
cormodel	String indicating the correlation model: "none" (default), "argyle" or "cole"
...	Allow for dot parameters

Value

A list with eight components. The function calculates parameters end (the iteration number of the last iteration) and thin_imp (thinning factor for multiple imputations) from the other inputs.

EB *Empirical Bayes predictor for random effects*

Description

This function can estimate random effect for a given set of model estimates and new user data. The unit may be new to the model. The methods implements the EB estimate (also known as BLUP) as described in Skrondral and Rabe-Hasketh, 2009, p. 683. This function can also provide the broken stick estimate for a given level, the sum of the global (fixed) and individual (random) effects. The current implementation does not provide prediction errors.

Usage

```
EB(model, y, X, Z = X, BS = TRUE)
```

Arguments

model	An object of class brokenstick.
y	A vector of new measurements for unit j, scaled in the same metric as the fitted model.
X	A nj * p matrix with fixed effects for unit j, typically produced by bs().
Z	A nj * q matrix with random effects for unit j. The default sets Z equal to X.
BS	A logical indicating whether broken stick estimates should be returned (BS = TRUE) or the random effects (BS = FALSE). The default is TRUE.

Value

A vector of length q containing the random effect or broken stick estimates for unit j.

Author(s)

Stef van Buuren 2023

References

Skrondal, A., Rabe-Hesketh, S. (2009). Prediction in multilevel generalized linear models. J. R. Statist. Soc. A, 172, 3, 659-687.

fitted.brokenstick *Calculate fitted values*

Description

Calculate fitted values

Usage

```
## S3 method for class 'brokenstick'
fitted(object, newdata = NULL, ...)
```

Arguments

object	A brokenstick object.
newdata	Optional. A data frame in which to look for variables with which to predict. The training data are used if omitted and if object$light is FALSE.
...	Additional arguments. Ignored.

Value

A numerical vector with predictions. The number of elements equals the number of rows in newdata. If newdata is not specified, the function looks for the training data in object as the element named data.

See Also

Other brokenstick: residuals.brokenstick()

fit_200 *Broken stick model with nine lines for 200 children*

Description

Object fit_200 has class brokenstick and contains the fitted broken stick model, including the training data and diagnostics.

Format

An object of class brokenstick, fitted by the brokenstick().

Details

The dataset was constructed as

```
knots <- round(c(0, 1, 2, 3, 6, 9, 12, 15, 18, 24)/12, 4)
fit_200 <- brokenstick(hgt_z ~ age | id, data = smocc_200,
                       knots = knots, seed = 1)
```

`fit_200_light` *Broken stick model with nine lines for 200 children (light)*

Description

Object `fit_200_light` has class `brokenstick` and stores the the model settings and parameter estimates.

Format

An object of class brokenstick, fitted by the `brokenstick()`.

Details

The datasets was constructed as

```
knots <- round(c(0, 1, 2, 3, 6, 9, 12, 15, 18, 24)/12, 4)
fit_200_light <- brokenstick(hgt_z ~ age | id, data = smocc_200,
                       knots = knots,
                       light = TRUE, seed = 1)
```

`get_knots` *Obtain the knots from a broken stick model*

Description

Obtain the knots from a broken stick model

Usage

```
get_knots(
  object,
  hide = c("right", "left", "boundary", "internal", "none"),
  whatknots = "all",
  what = "all"
)
```

Arguments

object	An object of class brokenstick
hide	Should output for knots be hidden in get, print, summary and plot functions? Can be "left", "right", "boundary", "internal" or "none". The default is "right".
whatknots	Deprecated. Use hide instead.
what	Deprecated. Use hide instead.

Value

A vector with knot locations, either both, internal only or boundary only, depending on hide. The result is NULL if object does not have proper class. Returns numeric(0) if there are no internal knots.

Examples

```
get_knots(fit_200, hide = "bo")
```

---

get_omega *Extract Variance and Correlation Components*

Description

Extracts variance-covariance or correlation matrix from a brokenstick object.

Usage

```
get_omega(
  x,
  hide = c("right", "left", "boundary", "internal", "none"),
  cor = FALSE,
  whatknots = "all",
  what = "cov"
)
```

Arguments

x	Object of class brokenstick
hide	Should output for knots be hidden in get, print, summary and plot functions? Can be "left", "right", "boundary", "internal" or "none". The default is "right".
cor	Logical. Should the function return the correlation matrix instead of the covariance matrix? The default is FALSE.
whatknots	Deprecated.
what	Deprecated.

Value

A numeric matrix, possibly with zero rows and columns if no names match

Examples

```
f1 <- brokenstick(hgt_z ~ age | id, smocc_200[1:1000, ], knots = 0:2, seed = 1)
get_omega(f1, cor = TRUE, hide = "boundary")
```

---

get_r2 *Obtain proportion of explained variance from a broken stick model*

Description

Obtain proportion of explained variance from a broken stick model

Usage

```
get_r2(object, newdata = NULL)
```

Arguments

object	An object of class brokenstick
newdata	Data on which r.squared must be calculated

Value

Proportion of explained variance

Examples

```
get_r2(fit_200)
get_r2(fit_200_light, newdata = smocc_200)
```

---

kr *Kasim-Raudenbush sampler for two-level normal model*

Description

Simulates posterior distributions of parameters from a two-level normal model with heterogeneous within-cluster variances (Kasim and Raudenbush, 1998). Imputations can be drawn as an extra step to the algorithm.

Usage

```
kr(y, x, g, control = control_kr())
```

Arguments

y	Vector with outcome value
x	Matrix with predictor value
g	Vector with group values
control	A list created by control_kr() that sets algorithmic options of the sampler and correlation model.

Details

The speed of the Kasim-Raudenbush sampler is almost independent of the number of random effect, and foremost depends on the total number of iterations.

The defaults start = 100, n = 200 and thin = 1 provide 200 parameter draws with a *reasonable* approximation to the variance-covariance matrix of the random effects.

For a closer approximations with 200 draws set control = control_kr(thin = 10) (*better*) or thin = 20 (*best*), at the expense of a linear increase in calculation time. Drawing fewer than 50 observations is not recommended, and such results are best treated as *indicative*.

It is possible to draw multiple imputations by setting the nimp parameter. For example, to draw five imputations for each missing outcome specify control = control_kr(nimp = 5).

Value

An object of class kr, basically a list with components:

```
* `beta`  Fixed effects
* `omega` Variance-covariance of random effects
* `sigma2_j` Residual variance per group
* `sigma2` Average residual variance
* `sample` Descriptive statistics about the data
* `imp`   Numeric matrix with `nimp` multiple imputations.
* `mod`   A list of objects of class [coda::mcmc()]
```

The number of rows in imp is equal to the number of missing values in the outcome vector y. The number of columns equals nimp.

Author(s)

Stef van Buuren, based on mice::mice.impute.2l.norm()

References

Kasim RM, Raudenbush SW. (1998). Application of Gibbs sampling to nested variance components models with heterogeneous within-group variance. Journal of Educational and Behavioral Statistics, 23(2), 93–116.

make_basis *Create linear splines basis*

Description

This function creates the basis function of a second-order (linear) splines at a user-specific set of break points.

Usage

```
make_basis(
  x,
  xname = "x",
  internal = NULL,
  boundary = range(x),
  degree = 1L,
  warn = TRUE
)
```

Arguments

x	numeric vector
xname	predictor name. Default is "x"
internal	a vector of internal knots, excluding boundary knots
boundary	vector of external knots
degree	the degree of the spline. The broken stick model requires linear splines, so the default is degree = 1. Setting degree = 0 yields (crisp) dummy coding, and one column less than for degree = 1.
warn	a logical indicating whether warnings from splines::bs() should be given.

Value

A matrix with length(x) rows and length(breaks) columns, with some extra attributes described by bs().

Note

Before version 0.54, it was standard practice that the knots array always included boundary[1L].

Author(s)

Stef van Buuren 2023

parse_formula *Parse formula for brokenstick model*

Description

A bare bones formula parser to extract variables names from formulas of `y ~ x | g`. It return the name of the first variable mentioned in each formula component.

Usage

```
parse_formula(f)
```

Arguments

`f`	formula object

Value

A `list` with elements `x`, `y` and `g`. Each element has length 1.

Author(s)

Stef van Buuren 2023

plot.brokenstick *Plot observed and fitted trajectories by group*

Description

The `plot` method for a `brokenstick` object plots the observed and fitted trajectories of one or more groups.

Usage

```
## S3 method for class 'brokenstick'
plot(x, newdata = NULL, ...)
```

Arguments

`x`	An object of class `brokenstick`.
`newdata`	Optional. A data frame in which to look for variables with which to predict. The training data are used if omitted and if `object$light` is `FALSE`.
`...`	Extra arguments passed down to `predict.brokenstick()` and `plot_trajectory()`.

Details

By default, `plot(fit)` will plot the observed and fitted data for the first three groups in the data. The default setting drops the fitted value at the right boundary knot from the display.

Value

An object of class ggplot2::ggplot.

Author(s)

Stef van Buuren 2023

See Also

predict.brokenstick, plot_trajectory.

Examples

```
## Not run:
# fit model on raw hgt with knots at 0, 1, 2 and 3 years
fit1 <- brokenstick(hgt ~ age | id, smocc_200, knots = 0:2)
gp <- c(10001, 10005, 10022)
plot(fit1, group = gp, xlab = "Age (years)", ylab = "Length (cm)")

# fit model on standard deviation score
fit2 <- brokenstick(hgt_z ~ age | id, smocc_200, knots = 0:2)
plot(fit2, group = gp, xlab = "Age (years)", ylab = "Length (SDS)")

# built-in model with 11 knots
plot(fit_200, group = gp, xlab = "Age (years)", ylab = "Length (SDS)")

# black and white version
plot(fit_200, group = gp, xlab = "Age (years)", ylab = "Length (SDS)",
    color_y = rep("black", 2), shape_y = 1, linetype_y = 3,
    color_yhat = rep("grey20", 2), shape_yhat = NA)

## End(Not run)
```

---

plot_trajectory *Plot observed and fitted trajectories from fitted brokenstick model*

Description

Plot observed and fitted trajectories from fitted brokenstick model

Usage

```
plot_trajectory(
  x,
  newdata = NULL,
  hide = c("right", "left", "boundary", "internal", "none"),
  .x = NULL,
  group = NULL,
 color_y = c(grDevices::hcl(240, 100, 40, 0.7), grDevices::hcl(240, 100, 40, 0.8)),
  size_y = 2,
  linetype_y = 1,
  shape_y = 19,
 color_yhat = c(grDevices::hcl(0, 100, 40, 0.7), grDevices::hcl(0, 100, 40, 0.8)),
  size_yhat = 2,
  linetype_yhat = 1,
  shape_yhat = 19,
  color_imp = c("grey80", "grey80"),
  size_imp = 2,
  ncol = 3L,
  xlab = NULL,
  ylab = NULL,
  xlim = NULL,
  ylim = NULL,
  show = c(TRUE, TRUE, FALSE),
  n_plot = 3L,
  scales = "fixed",
  theme = ggplot2::theme_light(),
  whatknots = "droplast",
  ...
)
```

Arguments

x	An object of class brokenstick.
newdata	A data.frame or matrix
hide	Character indicating which knots should
.x	The x argument of the predict.brokenstick() function.
group	A vector with group identifications
color_y	A character vector with two elements specifying the symbol and line color of the measured data points
size_y	Dot size of measured data points
linetype_y	Line type of data points
shape_y	Symbol for data points
color_yhat	A character vector with two elements specifying the symbol and line color of the predicted data points
size_yhat	Dot size of predicted data points

linetype_yhat	Line type of predicted data
shape_yhat	Symbol for predicted data
color_imp	A character vector with two elements specifying the symbol and line color of the imputed data
size_imp	Dot size of imputed data
ncol	Number of columns in plot
xlab	The label of the x-axis
ylab	The label of the y-axis
xlim	Vector of length 2 with range of x-axis
ylim	Vector of length 2 with range of y-axis
show	A logical vector of length 3. Element 1 specifies whether the observed data are plotted, element 2 specifies whether the broken stick are plotted, element 3 specifies whether imputations are plotted. The default is `c(TRUE, TRUE, FALSE)`.
n_plot	A integer indicating the number of individual plots. The default is 3, which plots the trajectories of the first three groups. The `n_plot` is a safety measure to prevent unintended plots of the entire data set.
scales	Axis scaling, e.g. `"fixed"`, `"free"`, and so on
theme	Plotting theme
whatknots	Deprecated.
...	Extra arguments passed down to `predict.brokenstick()`.

Value

An object of class `ggplot`

See Also

plot.brokenstick

`predict.brokenstick` *Predict from a* `brokenstick` *model*

Description

The predictions from a broken stick model coincide with the group-conditional means of the random effects. This function takes an object of class `brokenstick` and returns predictions in one of several formats. The user can calculate predictions for new persons, i.e., for persons who are not part of the fitted model, through the `x` and `y` arguments.

Usage

```
## S3 method for class 'brokenstick'
predict(
  object,
  newdata = NULL,
  ...,
  x = NULL,
  y = NULL,
  group = NULL,
  hide = c("right", "left", "boundary", "internal", "none"),
  shape = c("long", "wide", "vector"),
  include_data = TRUE,
  strip_data = TRUE,
  whatknots = "all"
)
```

Arguments

object	A brokenstick object.
newdata	Optional. A data frame in which to look for variables with which to predict. The training data are used if omitted and if object$light is FALSE.
...	Not used, but required for extensibility.
x	Optional. A numeric vector with values of the predictor. It could also be the special keyword x = "knots" replaces x by the positions of the knots.
y	Optional. A numeric vector with measurements.
group	A vector with group identifications
hide	Should output for knots be hidden in get, print, summary and plot functions? Can be "left", "right", "boundary", "internal" or "none". The default is "right".
shape	A string: "long" (default), "wide" or "vector" specifying the shape of the return value. Note that use of "wide" with many unique values in x creates an unwieldy, large and sparse matrix.
include_data	A logical indicating whether the observed data from object$data and newdata should be included into the return value. The default is TRUE. Use include_data = FALSE to keep only added data points (e.g. knots or observed data specified by x and y). Setting include_data = FALSE is useful in combination with shape = "wide" to avoid the warning Values from '.pred' are not uniquely identified. For convenience, in the special case x = "knots" the function overwrites include_data to FALSE to evade observed ages to show up in the wide matrix.
strip_data	Deprecated. Use include_data instead.
whatknots	Deprecated. Use hide instead.

Details

The function predict() calculates predictions for every row in newdata. If the user specifies no newdata argument, then the function sets newdata equal to the training data (object$data if

object$light is FALSE). For a light object without a newdata argument, the function throws the warning "Argument 'newdata' is required for a light brokenstick object." and returns NULL.

It is possible to tailor the behaviour of predict() through the x, y and group arguments. What exactly happens depends on which of these arguments is specified:

1. If the user specifies x, but no y and group, the function returns - for every group in newdata - predictions at the specified x values. This method will use the data from newdata.
2. If the user specifies x and y but no group, the function forms a hypothetical new group with the x and y values. This method uses no information from newdata, and also works for a light brokenstick object.
3. If the user specifies group, but no x or y, the function searches for the relevant data in newdata and limits its predictions to those groups. This is useful if the user needs a prediction for only one or a few groups. This does not work for a light brokenstick object.
4. If the user specifies x and group, but no y, the function will create new values for x in each group, search for the relevant data in newdata and provide predictions at values of x in those groups.
5. If the user specifies x, y and group, the function assumes that these vectors contain additional data on top on what is already available in newdata. The lengths of x, y and group must match. For a light brokenstick object, case effectively becomes case 6. See below.
6. As case 5, but now without newdata available. All data are specified through x, y and group and form a data frame. Matching to newdata is attempted, but as long as group id's are different from the training sample effectively new cases will be made.

Value

If shape == "long" a long data.frame of predictions. If x, y and group are not specified, the number of rows in the data frame is guaranteed to be the same as the number of rows in newdata.

If shape == "wide" a wide data.frame of predictions, one record per group. Note that this format could be inefficient if observations times vary between subjects.

If shape == "vector" a vector of predicted values, of all x-values and groups.

If the function finds no data, it throws a warnings and returns NULL.

Examples

```
library("dplyr")

# -- Data

train <- smocc_200[1:1198, ]
test <- smocc_200[1199:1940, ]
## Not run:
# -- Fit model

fit <- brokenstick(hgt_z ~ age | id, data = train, knots = 0:2, seed = 1)
fit_light <- brokenstick(hgt_z ~ age | id,
  data = train, knots = 0:2,
  light = TRUE, seed = 1
)
```

```
# -- Predict, standard cases

# Use train data, return column with predictions
pred <- predict(fit)
identical(nrow(train), nrow(pred))

# Predict without newdata, not possible for light object
predict(fit_light)

# Use test data
pred <- predict(fit, newdata = test)
identical(nrow(test), nrow(pred))

# Predict, same but using newdata with the light object
pred_light <- predict(fit_light, newdata = test)
identical(pred, pred_light)


# -- Predict, special cases


# -- Case 1: x, -y, -group

# Case 1: x as "knots", standard estimates, train sample (n = 124)
z <- predict(fit, x = "knots", shape = "wide")
head(z, 3)

# Case 1: x as values, linearly interpolated, train sample (n = 124)
z <- predict(fit, x = c(0.5, 1, 1.5), shape = "wide", include_data = FALSE)
head(z, 3)

# Case 1: x as values, linearly interpolated, test sample (n = 76)
z <- predict(fit, test, x = c(0.5, 1, 1.5), shape = "wide", include_data = FALSE)
head(z, 3)

# Case 1: x, not possible for light object
z <- predict(fit_light, x = "knots")

# -- Case 2: x, y, -group

# Case 2: form one new group with id = 0
predict(fit, x = "knots", y = c(1, 1, 0.5, 0), shape = "wide")

# Case 2: works also for a light object
predict(fit_light, x = "knots", y = c(1, 1, 0.5, 0), shape = "wide")


# -- Case 3: -x, -y, group

# Case 3: Predict at observed age for subset of groups, training sample
pred <- predict(fit, group = c(10001, 10005, 10022))
head(pred, 3)
```

```
# Case 3: Of course, we cannot do this for light objects
pred_light <- predict(fit_light, group = c(10001, 10005, 10022))

# Case 3: We can use another sample. Note there is no child 999
pred <- predict(fit, test, group = c(11045, 11120, 999))
tail(pred, 3)

# Case 3: Works also for a light object
pred_light <- predict(fit_light, test, group = c(11045, 11120, 999))
identical(pred, pred_light)

# -- Case 4: x, -y, group

# Case 4: Predict at specified x, only in selected groups, train sample
pred <- predict(fit, x = c(0.5, 1, 1.25), group = c(10001, 10005, 10022),
        include_data = FALSE)
pred

# Case 4: Same, but include observed data and sort
pred_all <- predict(fit,
  x = c(0.5, 1, 1.25), group = c(10001, 10005, 10022)) %>%
  dplyr::arrange(id, age)

# Case 4: Applies also to test sample
pred <- predict(fit, test, x = c(0.5, 1, 1.25), group = c(11045, 11120, 999),
 include_data = FALSE)
pred

# Case 4: Works also with light object
pred_light <- predict(fit_light, test, x = c(0.5, 1, 1.25),
  group = c(11045, 11120, 999), include_data = FALSE)
identical(pred_light, pred)

# -- Case 5: x, y, group

# Case 5: Add new data to training sample, and refreshes broken stick
# estimate at age x.
# Note that novel child (not in train) 999 has one data point
predict(fit,
  x = c(0.9, 0.9, 0.9), y = c(1, 1, 1),
  group = c(10001, 10005, 999), include_data = FALSE)

# Case 5: Same, but now for test sample. Novel child 899 has two data points
predict(fit, test,
  x = c(0.5, 0.9, 0.6, 0.9),
  y = c(0, 0.5, 0.5, 0.6), group = c(11045, 11120, 899, 899),
  include_data = FALSE)

# Case 5: Also works for light object
predict(fit_light, test,
  x = c(0.5, 0.9, 0.6, 0.9),
  y = c(0, 0.5, 0.5, 0.6), group = c(11045, 11120, 899, 899),
```

```
  include_data = FALSE)


# -- Case 6: As Case 5, but without previous data

# Case 6: Same call as last, but now without newdata = test
# All children are de facto novel as they do not occur in the training
# or test samples.
# Note: Predictions for 11045 and 11120 differ from prediction in Case 5.
predict(fit,
  x = c(0.5, 0.9, 0.6, 0.9),
  y = c(0, 0.5, 0.5, 0.6), group = c(11045, 11120, 899, 899))

# This also work for the light brokenstick object
predict(fit_light,
  x = c(0.5, 0.9, 0.6, 0.9),
  y = c(0, 0.5, 0.5, 0.6), group = c(11045, 11120, 899, 899))

## End(Not run)
```

`print.brokenstick` *Print brokenstick object*

Description

Print brokenstick object

Usage

```
## S3 method for class 'brokenstick'
print(
  x,
  digits = getOption("digits"),
  ...,
  hide = c("right", "left", "boundary", "internal", "none")
)
```

Arguments

`x`	A `brokenstick` object
`digits`	minimal number of *significant* digits, see `print.default`.
`...`	further arguments passed to or from other methods.
`hide`	Should output for boundary knots be hidden in the print, summary and plot functions? Can be `"right"`, `"left"`,`"boundary"`, `"internal"` or `"none"`. If not specified, it is read from the field `x$hide`.

residuals.brokenstick *Extract residuals from brokenstick model*

Description

Extract residuals from brokenstick model

Usage

```
## S3 method for class 'brokenstick'
residuals(object, newdata = NULL, ...)
```

Arguments

object	A brokenstick object.
newdata	Optional. A data frame in which to look for variables with which to predict. The training data are used if omitted and if object$light is FALSE.
...	Additional arguments. Ignored.

Value

A numerical vector with residuals The number of elements equals the number of rows in newdata. If newdata is not specified, the function looks for the training data in object as the element named data.

See Also

Other brokenstick: fitted.brokenstick()

robust_chol2inv *Robust inversion of symmetric matrices*

Description

Attempts to compute the inverse of a symmetric matrix using Cholesky decomposition. If the matrix is not positive definite, a small ridge value is added. If it still fails, a diagonal fallback is returned.

Usage

```
robust_chol2inv(Sigma, eps = 1e-08, fallback_diag = TRUE)
```

Arguments

Sigma	A symmetric matrix to invert.
eps	Ridge value added to the diagonal to regularize the matrix.
fallback_diag	Logical. If TRUE, return a diagonal matrix as a fallback when Cholesky fails.

Value

A matrix of the same dimension as `Sigma`, representing its regularized inverse.

`set_control` *Set controls to steer calculations*

Description

Set controls to steer calculations

Usage

```
set_control(
  method = c("kr", "lmer"),
  kr = control_kr(...),
  lmer = lmerControl(check.nobs.vs.nRE = "warning"),
  ...
)
```

Arguments

`method`	String indicating estimation method: `"kr"` or `"lmer"`
`kr`	A list generated by control_kr.
`lmer`	A list generated by lme4::lmerControl. The default is set to `lmerControl(check.nobs.vs.nRE = "warning")`, which turns fatal errors with respect the number of parameters into warnings. Use `lmerControl(check.nobs.vs.nRE = "ignore")` to silence `lmer()`.
`...`	Forwards arguments to `control_kr()`

Value

For method `"kr"`, a list returned by `control_kr()`. For method `"lmer"`, an object of class `lmerControl`. For other methods, `set_control()` returns `NULL`.

Examples

```
# defaults
control <- set_control()
control
```

smocc_200 *Infant growth of 0-2 years, SMOCC data extract*

Description

Longitudinal height and weight measurements during ages 0-2 years for a representative sample of 1933 Dutch children born in 1988-1989. The dataset `smocc_200` is sample of size 200 from the full data.

Format

A tibble with 1942 rows and 7 columns:

id ID, unique `id` of each child (numeric)

age Decimal age, 0-2.68 years (numeric)

sex Sex, `"male"` or `"female"` (character)

ga Gestational age, completed weeks (numeric)

bw Birth weight in grammes (numeric)

hgt Height measurement in cm (numeric)

hgt_z Height in SDS relative Fourth Dutch Growth Study 1997 (numeric)

Source

Herngreen WP, van Buuren S, van Wieringen JC, Reerink JD, Verloove-Vanhorick SP & Ruys JH (1994). Growth in length and weight from birth to 2 years of a representative sample of Netherlands children (born in 1988-89) related to socio-economic status and other background characteristics. *Annals of Human Biology*, **21**, 449-463.

summary.brokenstick *Create summary of brokenstick object*

Description

Create summary of brokenstick object

Usage

```
## S3 method for class 'brokenstick'
summary(
  object,
  ...,
  cor = FALSE,
  lower = TRUE,
  hide = c("right", "left", "boundary", "internal", "none")
)
```

Arguments

object	A brokenstick object
...	additional arguments affecting the summary produced.
cor	Logical. Should the function return the correlation matrix instead of the covariance matrix? The default is FALSE.
lower	Logical. Print lower triangle of correlation/covariance matrix?
hide	Should output for boundary knots be hidden in the print, summary and plot functions? Can be "left", "right", "boundary", "internal" or "none". If not specified, it is read from the field object$hide.

---

weightloss *Weight loss self-measurement data*

Description

Longitudinal weight measurements from 12 individuals with 63 daily measurement under three conditions.

Format

A data.frame with 695 rows and 6 columns:

subject ID, consecutive person number 1-12 (integer)

day Measurement day, 0-62 (integer)

sex Sex, 1 = male, 0 = female (integer)

week Week number, 1-9 (integer)

condition Condition (control, diet, activity) (factor)

body_weight Body weight in kg (numeric)

Note

Constructed from file pone.0232680.s001.csv. We renumbered subject to consecutive integers 1-2 (as in the paper), corrected an error in the condition variable for subjects 4 and 12 to match the paper's Figure 4, and filtered the records to the ones woth an observed body_weight variable.

Source

Krone T, Boessen R, Bijlsma S, van Stokkum R, Clabbers NDS, Pasman WJ (2020). The possibilities of the use of N-of-1 and do-it-yourself trials in nutritional research. *PloS ONE*, **15**, 5, e0232680.

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