

# Package ‘bamlss’

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**Title** Bayesian Additive Models for Location, Scale, and Shape (and Beyond)

**Description** Infrastructure for estimating probabilistic distributional regression models in a Bayesian framework.

The distribution parameters may capture location, scale, shape, etc. and every parameter may depend

on complex additive terms (fixed, random, smooth, spatial, etc.) similar to a generalized additive model.

The conceptual and computational framework is introduced in Umlauf, Klein, Zeileis (2019) [doi:10.1080/10618600.2017.1407325](https://doi.org/10.1080/10618600.2017.1407325) and the R package in Umlauf, Klein, Simon, Zeileis (2019) [arXiv:1909.11784](https://arxiv.org/abs/1909.11784).

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**License** GPL-2 | GPL-3

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`bamlss-package`*Bayesian Additive Models for Location Scale and Shape (and Beyond)*

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### Description

The **bamlss** package is a general tool for complex Bayesian regression modeling with structured additive predictors based on Markov chain Monte Carlo simulation. The design of this package substantially focuses on maximum flexibility and easy integration of new code and/or standalone systems. The package makes heavy use of `mgcv` infrastructures to build up all necessary model matrices and information from which it is relatively easy for the user to construct estimation algorithms or interfaces to existing software packages. The package can also be seen as an harmonized framework for regression modeling since it does not restrict to any type of problem. The main function in this package is `bamlss`, which is a wrapper function that calls optimizer and/or sampling functions for fitting Bayesian additive models for location scale and shape (and beyond). These model fitting functions can be exchanged by the user. Moreover, the package contains numerous functions for creating post-estimation results like summary statistics and effect plots etc.

### Author(s)

Nikolaus Umlauf, Nadja Klein, Achim Zeileis.

### References

Umlauf N, Klein N, Zeileis A (2019). BAMLSS: Bayesian Additive Models for Location, Scale and Shape (and Beyond). *Journal of Computational and Graphical Statistics*, **27**(3), 612–627. doi: [10.1080/10618600.2017.1407325](https://doi.org/10.1080/10618600.2017.1407325)

Umlauf N, Klein N, Simon T, Zeileis A (2019). “bamlss: A Lego Toolbox for Flexible Bayesian Regression (and Beyond).” arXiv:1909.11784, arXiv.org E-Print Archive. <https://arxiv.org/abs/1909.11784>

### See Also

[bamlss](#), [bamlss.frame](#)

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`Austria`*Austria States and Topography*

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### Description

These two data sets `Austria` and `AustriaTopo` provide the states of Austria as a [SpatialPolygonsDataFrame](#) and the topography of Austria as data frame.

### Usage

```
data("Austria")
```

**Format**

The AustriaTopo data contains the following variables:

**lon:** Numeric, longitude coordinates.

**lat:** Numeric, latitude coordinates.

**alt:** Numeric, altitude.

**References**

Austria (2016). Nuts Einheiten, *STATISTIK AUSTRIA*. [http://www.statistik.at/web\\_de/klassifikationen/regional](http://www.statistik.at/web_de/klassifikationen/regional)

Austria Topography (2016). *National Centers for Environmental Information, National Oceanic and Atmospheric Administration (NOAA)*. <https://www.ngdc.noaa.gov/mgg/global/global.html>

**Examples**

```
data("Austria")
plot(Austria)
print(head(AustriaTopo))
```

---

bamlss	<i>Fit Bayesian Additive Models for Location Scale and Shape (and Beyond)</i>
--------	---

---

**Description**

This is the main model fitting function of the package. Function `bamlss()` is a wrapper function that parses the data and the model formula, or extended `bamlss.formula`, as well as the `bamlss.family` into a `bamlss.frame`. The `bamlss.frame` then holds all model matrices and information that is needed for setting up estimation engines. The model matrices are based on `mgcv` infrastructures, i.e., smooth terms are constructed using `smooth.construct` and `smoothCon`. Therefore, all `mgcv` model term constructors like `s`, `te`, `t2` and `ti` can be used. Identifiability conditions are imposed using function `gam.side`.

After the `bamlss.frame` is set up function `bamlss()` applies optimizer and/or sampling functions. These functions can also be provided by the user. See the details below on how to create new engines to be used with function `bamlss()`.

Finally, the estimated parameters and/or samples are used to create model output results like summary statistics or effect plots. The computation of results may also be controlled by the user.

**Usage**

```
bamlss(formula, family = "gaussian", data = NULL,
       start = NULL, knots = NULL, weights = NULL,
       subset = NULL, offset = NULL, na.action = na.omit,
       contrasts = NULL, reference = NULL, transform = NULL,
       optimizer = NULL, sampler = NULL, samplestats = NULL,
       results = NULL, cores = NULL, sleep = NULL,
       combine = TRUE, model = TRUE, x = TRUE,
       light = FALSE, ...)
```

## Arguments

formula	A formula or extended formula, i.e., the formula can be a <a href="#">list</a> of formulas where each list entry specifies the details of one parameter of the modeled response distribution, see <a href="#">bamlss.formula</a> . For incorporating smooth terms, all model term constructors implemented in <a href="#">mgcv</a> such as <a href="#">s</a> , <a href="#">te</a> and <a href="#">ti</a> can be used, amongst others.
family	A <a href="#">bamlss.family</a> object, specifying the details of the modeled distribution such as the parameter names, the density function, link functions, etc. Can be a character without the <code>"_bamlss"</code> extension of the <a href="#">bamlss.family</a> name.
data	A <a href="#">data.frame</a> or <a href="#">list</a> containing the model response variable(s) and covariates specified in the formula. By default the variables are taken from <code>environment(formula)</code> : typically the environment from which <code>bamlss</code> is called.
start	A named numeric vector containing starting values to be send to the optimizer and/or sampler function. For a possible naming convention for the parameters see function <a href="#">parameters</a> , but this is not restrictive and engine specific.
knots	An optional list containing user specified knots, see the documentation of function <a href="#">gam</a> .
weights	Prior weights on the data.
subset	An optional vector specifying a subset of observations to be used in the fitting process.
offset	Can be used to supply model offsets for use in fitting.
na.action	A function which indicates what should happen when the data contain NA's. The default is set by the <code>na.action</code> setting of <a href="#">options</a> , and is <a href="#">na.omit</a> if set to NULL.
contrasts	An optional list. See the <code>contrasts.arg</code> of <a href="#">model.matrix.default</a> .
reference	A character specifying a reference category, e.g., when fitting a multinomial model.
transform	A transformer function that is applied on the <a href="#">bamlss.frame</a> . See, e.g., function <a href="#">randomize</a> and <a href="#">bamlss.engine.setup</a> .
optimizer	An optimizer function that returns, e.g., posterior mode estimates of the parameters as a named numeric vector. The default optimizer function is <a href="#">opt_bfit</a> . If set to FALSE, no optimizer function will be used.
sampler	A sampler function that returns a matrix of samples, the columns represent the parameters, the rows the iterations. The returned matrix must be coerced to an object of class <code>"mcmc"</code> , see <a href="#">as.mcmc</a> . The default sampler function is <a href="#">sam_GMCMC</a> . If set to FALSE, no sampler function will be used.
samplestats	A function computing statistics from samples, per default function <a href="#">samplestats</a> is used. If set to FALSE, no <code>samplestats</code> function will be used. Note that this option is crucial for very large datasets, as computing statistics from samples this way may be very time consuming!
results	A function computing results from the parameters and/or samples, e.g., for creating effect plots, see function <code>link{results.bamlss.default}</code> . If set FALSE no results function will be used.

cores	An integer specifying the number of cores that should be used for the sampler function. This is based on function <code>mclapply</code> of the <b>parallel</b> package.
sleep	Time the system should sleep before the next core is started.
combine	If samples are computed on multiple cores, should the samples be combined into one <code>mcmc</code> matrix?
model	If set to <code>FALSE</code> the model frame used for modeling is not part of the return value.
x	If set to <code>FALSE</code> the model matrices are not part of the return value.
light	Should the returned object be lighter, i.e., if <code>light = TRUE</code> the returned object will not contain the <code>model.frame</code> and design and penalty matrices are deleted.
...	Arguments passed to the transformer, optimizer, sampler, results and <code>samplestats</code> function.

## Details

The main idea of this function is to provide infrastructures that make it relatively easy to create estimation engines for new problems, or write interfaces to existing software packages.

The steps that are performed within the function are:

- First, the function parses the data, the formula or the extended `bamlss.formula` as well as the `bamlss.family` into a model frame like object, the `bamlss.frame`. This object holds all necessary model matrices and information that is needed for subsequent model fitting engines. Per default, all package `mgcv` smooth term constructor functions like `s`, `te`, `t2` and `ti` can be used (see also function `smooth.construct`), however, even special user defined constructors can be included, see the manual of `bamlss.frame`.
- In a second step, the `bamlss.frame` can be transformed, e.g., if a mixed model representation of smooth terms is needed, see function `randomize`.

- Then an optimizer function is started, e.g., a function that finds posterior mode estimates of the parameters. A convention for model fitting engines is that such functions should have the following arguments:

```
optimizer(x,y,family,start,weights,offset,...)
```

Internally, function `bamlss()` will send the `x` object that holds all model matrices, the response `y` object, the `family` object, starting values for the parameters, possible `weights` and `offsets` of the created `bamlss.frame` to the optimizer function (see the manual of `bamlss.frame` for more details on the `x`, `y` and other objects). The job of the optimizer is to return a named numeric vector of optimum parameters. The names of the parameters should be such that they can be uniquely mapped to the corresponding model matrices in `x`. See function `parameters` for more details on parameter names. The default optimizer function is `bfit`. The optimizer can return more information than only the optimum parameters. It is possible to return a list, the convention here is that an element named "parameters" then holds the named vector of estimated parameters. Possible other return values could be fitted values, the Hessian matrix, information criteria or information about convergence of the algorithm, etc. Note that the parameters are simply added to the `bamlss.frame` in an (list) entry named `parameters`.

- After the optimization step, a sampler function is started. The arguments of such sampler functions are the same as for the optimizer functions
- ```
sampler(x,y,family,start,weights,offset,...)
```

Sampler functions must return a matrix of samples, each row represents one iteration and the matrix can be coerced to `mcmc` objects. The function may return a list of samples, e.g., if multiple chains are returned each list entry then holds one sample matrix of one chain. The column names of the sample matrix should be the same as the names of estimated parameters. For a possible naming convention see function `parameters`, which ensures unique mapping of samples with the model matrices in the `x` object of the `bamlss.frame`. The samples are added to the `bamlss.frame` in an (list) entry named `samples`.

- Next, the `samplestats` function is applied. This function can compute any quantity from the samples and the `x` object, the arguments of such functions are `samplestats(samples, x, y, family, ...)` where argument `samples` are the samples returned from the sampler function, and `x`, `y` and `family` are the same objects as passed to the optimizer and or sampler functions. For example, the default function in `bamlss()` for this task is also called `samplestats` and returns the mean of the log-likelihood and the log-posterior computed of all samples, as well as the DIC.
- The last step is to compute more complex information about the model using the `results` function. The arguments of such `results` functions are `results(bamlss.frame, ...)` here, the full `bamlss.frame` including possible parameters and samples is passed to the function within `bamlss()`. The default function for this task is `results.bamlss.default` which returns an object of class `"bamlss.results"` for which generic plotting functions are and a `summary` function is provided. Hence, the user can control the output of the model, the plotting and summary statistics, too.

Note that function `transform()`, `optimizer()`, `sampler()`, `samplestats()` and `results()` can be provided from the `bamlss.family` object, e.g., if a `bamlss.family` object has an element named `"optimizer"`, which represents a valid optimizer function such as `bfit`, exactly this optimizer function will be used as a default when using the family.

## Value

An object of class `"bamlss"`. The object is in principle only a slight extension of a `bamlss.frame`, i.e., if an optimizer is applied it will hold the estimated parameters in an additional element named `"parameters"`. If a sampler function is applied it will additionally hold the samples in an element named `"samples"`. The same mechanism is used for `results` function.

If the optimizer function computes additional output next to the parameters, this will be saved in an element named `"model.stats"`. If a `samplestats` function is applied, the output will also be saved in the `"model.stats"` element.

Additionally, all functions that are called are saved as attribute `"functions"` in the returned object.

## Author(s)

Nikolaus Umlauf, Nadja Klein, Achim Zeileis.

## References

Umlauf N, Klein N, Zeileis A (2019). BAMLSS: Bayesian Additive Models for Location, Scale and Shape (and Beyond). *Journal of Computational and Graphical Statistics*, **27**(3), 612–627. doi: [10.1080/10618600.2017.1407325](https://doi.org/10.1080/10618600.2017.1407325)



Umlauf N, Klein N, Simon T, Zeileis A (2019). “bamlss: A Lego Toolbox for Flexible Bayesian Regression (and Beyond).” arXiv:1909.11784, arXiv.org E-Print Archive. <https://arxiv.org/abs/1909.11784>

## See Also

[bamlss.frame](#), [family.bamlss](#), [bamlss.formula](#), [randomize](#), [bamlss.engine.setup](#), [opt\\_bfit](#), [sam\\_GMCMC](#), [continue](#), [coef.bamlss](#), [parameters](#), [predict.bamlss](#), [plot.bamlss](#)

## Examples

```
## Not run: ## Simulated data example.
d <- GAMart()
f <- num ~ s(x1) + s(x2) + s(x3) + te(lon, lat)
b <- bamlss(f, data = d)
summary(b)
plot(b)
plot(b, which = 3:4)
plot(b, which = "samples")

## Use of optimizer and sampler functions:
## * first run optimizer,
b1 <- bamlss(f, data = d, optimizer = opt_bfit, sampler = FALSE)
print(b1)
summary(b1)

## * afterwards, start sampler with starting values,
b2 <- bamlss(f, data = d, start = coef(b1), optimizer = FALSE, sampler = sam_GMCMC)
print(b2)
summary(b2)

## Continue sampling.
b3 <- continue(b2, n.iter = 12000, burnin = 0, thin = 10)
plot(b3, which = "samples")
plot(b3, which = "max-acf")
plot(b3, which = "max-acf", burnin = 500, thin = 4)

## End(Not run)
```

---

bamlss.engine.helpers *BAMLSS Engine Helper Functions*

---

## Description

These functions can be useful when setting up new model fitting engines that are based on the setup function [bamlss.engine.setup](#). See the examples.

**Usage**

```
## Functions to extract parameter states.
get.par(x, what = NULL)
get.state(x, what = NULL)
set.par(x, replacement, what)

## Function for setting starting values.
set.starting.values(x, start)
```

**Arguments**

|             |                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| x           | For function <code>get.par()</code> and <code>set.par()</code> argument x is a named numeric vector. For function <code>get.state()</code> argument x is an object of the <code>smooth.construct</code> list that is processed by function <code>bamlss.engine.setup</code> , i.e., which has a "state" object. For function <code>set.starting.values()</code> argument x is the x list, as returned from function <code>bamlss.frame</code> . |
| what        | The name of the parameter(s) that should be extracted or replaced.                                                                                                                                                                                                                                                                                                                                                                              |
| replacement | The value(s) that should be used for replacement.                                                                                                                                                                                                                                                                                                                                                                                               |
| start       | The named numeric vector of starting values. The name convention is based on function <code>parameters</code> .                                                                                                                                                                                                                                                                                                                                 |

**See Also**

[bamlss.engine.setup](#)

**Examples**

```
## Create a bamlss.frame.
d <- GAMart()
bf <- bamlss.frame(num ~ s(x1) + s(x2) + te(lon,lat), data = d, family = "gaussian")
names(bf$x$mu$smooth.construct)

## Use the setup function for
## adding state elements.
bf$x <- bamlss.engine.setup(bf$x, df = c("s(x1)" = 1, "s(x2)" = 3))
names(bf$x$mu$smooth.construct)

## Extract regression coefficients.
get.state(bf$x$mu$smooth.construct[["te(lon,lat)"]], "b")

## Extract smoothing variances.
get.state(bf$x$mu$smooth.construct[["te(lon,lat)"]], "tau2")

## More examples.
state <- bf$x$mu$smooth.construct[["te(lon,lat)"]]$state
get.par(state$parameters, "b")
get.par(state$parameters, "tau2")

state$parameters <- set.par(state$parameters, c(0.1, 0.5), "tau2")
get.par(state$parameters, "tau2")
```

```
## Setting starting values.
start <- c("mu.s.s(x1).b" = 1:9, "mu.s.s(x1).tau2" = 0.1)
bf$x <- set.starting.values(bf$x, start = start)
get.state(bf$x$mu$smooth.construct[["s(x1)"]], "b")
get.state(bf$x$mu$smooth.construct[["s(x1)"]], "tau2")
```

---

bamlss.engine.setup     *BAMLSS Engine Setup Function*

---

## Description

This function takes the `x` object of a `bamlss.frame` and adds additional objects that are useful for model fitting engines. This is applied only for 'regular' terms, e.g., as created by `s` and `te`. For special model terms the corresponding `smooth.construct` method is in charge of this (see also the examples for function `bfit`).

## Usage

```
bamlss.engine.setup(x, update = "iwls", propose = "iwlsC_gp",
  do.optim = NULL, df = NULL, parametric2smooth = TRUE, ...)
```

## Arguments

|                                |                                                                                                                                                                                                                                                                                                                                                                                     |
|--------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>x</code>                 | The <code>x</code> list, as returned from function <code>bamlss.frame</code> , holding all model matrices and other information that is used for fitting the model.                                                                                                                                                                                                                 |
| <code>update</code>            | Sets the updating function for model terms, see function <code>bfit</code> .                                                                                                                                                                                                                                                                                                        |
| <code>propose</code>           | Sets the propose function for model terms, see function <code>GMCMC</code> .                                                                                                                                                                                                                                                                                                        |
| <code>do.optim</code>          | Adds list element "do.optim" in the "state" element, see the details below.                                                                                                                                                                                                                                                                                                         |
| <code>df</code>                | The initial degrees of freedom that should be assigned to a smooth model term, based on the trace of the smoother matrix. Note that <code>df</code> can be a named numeric vector. If the names match the labels of the model terms, the corresponding <code>df</code> are used, e.g., <code>df = c("s(x1)" = 1, "s(x2)" = 2)</code> sets different <code>dfs</code> for each term. |
| <code>parametric2smooth</code> | Should parametric model terms be transformed into an artificial smooth model term and be added to the "smooth.construct" object within the <code>x</code> list? This feature is handy, since algorithms can then cycle over the "smooth.construct" object, only.                                                                                                                    |
| <code>...</code>               | Currently not used.                                                                                                                                                                                                                                                                                                                                                                 |

## Details

For each model term in the "smooth.construct" object of the x list (as returned from [bamlss.frame](#)), this function adds a named list called "state" with the following entries:

- "parameters": A numeric vector. Regression coefficients are named with "b", smooth variances are named with "tau2".
- "fitted.values": Given the "parameters", the actual fitted values of the model term.
- "edf": Given the smoothing variances, the actual equivalent degrees of freedom (edf) of the model term.
- "do.optim": Should an optimizer function try to find optimum smoothing variances?

The state will be changed in each iteration and can be passed outside an updating function.

Additionally, if missing in the xt argument of a model term (see, e.g., function [s](#) for xt) the function adds the corresponding log-prior and its first and second order derivatives w.r.t. regression coefficients in functions [grad\(\)](#) and [hess\(\)](#).

Also, objects named "lower" and "upper" are added to each model term. These indicate the lower and upper boundaries of the parameter space.

## Value

A transformed x list, as returned from function [bamlss.frame](#).

## See Also

[bamlss.frame](#), [bfit](#), [GMCMC](#), [get.par](#), [set.par](#), [get.state](#)

## Examples

```
d <- GAMart()
bf <- bamlss.frame(num ~ s(x1) + s(x2), data = d, family = "gaussian")
names(bf$x$mu$smooth.construct)
bf$x <- bamlss.engine.setup(bf$x, df = c("s(x1)" = 1, "s(x2)" = 3))
names(bf$x$mu$smooth.construct)
names(bf$x$mu$smooth.construct[["s(x1)"]])
names(bf$x$mu$smooth.construct[["s(x1)"]])$state)
sapply(bf$x$mu$smooth.construct, function(x) {
  c(x$state$edf, get.state(x, "tau2"))
})
```

## Description

This function creates an extended BAMLSS [formula](#). In combination with a [bamlss.family](#) object, each parameter of the response distribution is linked to a single formula. If no formula is supplied for a parameter, a simple intercept only model is created. Moreover, the function identifies hierarchical structures, see the examples. This function is useful for creating complex [model.frames](#) for (hierarchical) multi-parameter models and is used by function [bamlss.frame](#).

**Usage**

```
bamlss.formula(formula, family = NULL, specials = NULL, env = NULL, ...)
```

**Arguments**

|          |                                                                                                                                                                                                                                                                                             |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| formula  | A simple <a href="#">formula</a> , or a <a href="#">list</a> of simple formulae, or an extended <a href="#">Formula</a> . For formula lists or extended <a href="#">Formulae</a> , each single formula represents one model for the respective parameter as specified in the family object. |
| family   | A <a href="#">bamlss.family</a> object.                                                                                                                                                                                                                                                     |
| specials | A character vector specifying special functions to be used within formulae, see <a href="#">terms.object</a> .                                                                                                                                                                              |
| env      | The environment that should be assigned to the formula.                                                                                                                                                                                                                                     |
| ...      | Arguments passed to the family.                                                                                                                                                                                                                                                             |

**Value**

A named list of class "bamlss.formula". Each list entry specifies a model, e.g., for one parameter of a provided [bamlss.family](#) object. Each entry (parameter model) then holds:

|              |                                                                                                                                                                                                                                          |
|--------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| formula      | A simple <a href="#">formula</a> .                                                                                                                                                                                                       |
| fake.formula | A formula with all function calls being dropped, e.g., the formula $y \sim s(x1) + s(x2)$ is represented in the <code>fake.formula</code> entry as $y \sim x1 + x2$ . The <code>fake.formula</code> is useful for creating model frames. |

**See Also**

[bamlss](#), [bamlss.frame](#), [bamlss.family](#)

**Examples**

```
## Simple formula without family object.
f <- bamlss.formula(y ~ x1 + s(x2))
print(f)
print(str(f))

## Complex formula with list of formulae.
f <- list(
  y1 ~ x1 + s(x2),
  y2 ~ x3 + te(lon, lat),
  u ~ x4 + x1
)

f <- bamlss.formula(f)
print(f)
print(names(f))

## Same formula but using extended formulae
## of package Formula.
f <- y1|y2|u ~ x1 + s(x2)|x3 + te(lon,lat)|x4 + x1
```

```

f <- bamlss.formula(f)
print(f)
print(names(f))

## Using a bamlss family object, e.g., gaussian_bamlss().
## The family has two parameters, mu and sigma, for
## each parameter one formula is returned. If no
## formula is specified an intercept only model is
## generated for the respective parameter.
f <- bamlss.formula(y ~ x1 + s(x2), family = gaussian_bamlss)

## Note, same as:
f <- bamlss.formula(y ~ x1 + s(x2), family = "gaussian")
print(f)

## Specify model for parameter sigma, too
f <- list(
  y ~ x1 + s(x2),
  sigma ~ x2 + te(lon, lat)
)
f <- bamlss.formula(f, family = "gaussian")
print(f)

## With complex hierarchical structures,
## each parameter is another list of formulae,
## indicated by the h1,...,hk, names.
f <- list(
  y ~ x1 + s(x2) + id1,
  sigma ~ x2 + te(lon, lat) + id2,
  id1 ~ s(x3) + x4 + s(id3),
  id3 ~ x5 + s(x5, x6),
  id2 ~ x7
)
f <- bamlss.formula(f, family = "gaussian")
print(f)

```

---

bamlss.frame

*Create a Model Frame for BAMLSS*


---

## Description

This function parses the data and the model formula, or extended `bamlss.formula`, as well as the `bamlss.family` into a `bamlss.frame` object. The `bamlss.frame` then holds all model matrices and information that is needed for setting up estimation engines.

## Usage

```

bamlss.frame(formula, data = NULL, family = "gaussian",
  weights = NULL, subset = NULL, offset = NULL,
  na.action = na.omit, contrasts = NULL,

```

```
knots = NULL, specials = NULL, reference = NULL,
model.matrix = TRUE, smooth.construct = TRUE,
ytype = c("matrix", "vector", "integer"),
scale.x = FALSE, scale.d = FALSE, ...)
```

## Arguments

|                  |                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| formula          | A formula or extended formula, i.e., the formula can be a <a href="#">list</a> of formulas where each list entry specifies the details of one parameter of the modeled response distribution, see <a href="#">bamlss.formula</a> . For incorporating smooth terms, all model term constructors implemented in <a href="#">mgcv</a> such as <a href="#">s</a> , <a href="#">te</a> and <a href="#">ti</a> can be used, amongst others. |
| data             | A <a href="#">data.frame</a> or <a href="#">list</a> containing the model response variable(s) and covariates specified in the formula. By default the variables are taken from environment(formula): typically the environment from which <a href="#">bamlss</a> is called.                                                                                                                                                          |
| family           | A <a href="#">bamlss.family</a> object, specifying the details of the modeled distribution such as the parameter names, the density function, link functions, etc.                                                                                                                                                                                                                                                                    |
| weights          | Prior weights on the data.                                                                                                                                                                                                                                                                                                                                                                                                            |
| subset           | An optional vector specifying a subset of observations to be used in the fitting process.                                                                                                                                                                                                                                                                                                                                             |
| offset           | Can be used to supply model offsets for use in fitting.                                                                                                                                                                                                                                                                                                                                                                               |
| na.action        | A function which indicates what should happen when the data contain NA's. The default is set by the na.action setting of <a href="#">options</a> , and is <a href="#">na.omit</a> if set to NULL.                                                                                                                                                                                                                                     |
| contrasts        | An optional list. See the contrasts.arg of <a href="#">model.matrix.default</a> .                                                                                                                                                                                                                                                                                                                                                     |
| knots            | An optional list containing user specified knots, see the documentation of function <a href="#">gam</a> .                                                                                                                                                                                                                                                                                                                             |
| specials         | Specify new special terms here to be used with the <a href="#">bamlss.formula</a> , see also <a href="#">terms.object</a> .                                                                                                                                                                                                                                                                                                           |
| reference        | A character specifying a reference category, e.g., when fitting a multinomial model.                                                                                                                                                                                                                                                                                                                                                  |
| model.matrix     | Logical, should model matrices for linear parts be returned?                                                                                                                                                                                                                                                                                                                                                                          |
| smooth.construct | Logical, should model matrices, e.g., as returned from <a href="#">smooth.construct</a> and <a href="#">smoothCon</a> be part of returned <a href="#">bamlss.frame</a> ?                                                                                                                                                                                                                                                              |
| ytype            | For categorical responses, should the response be a vector or matrix. If ytype == "matrix" <a href="#">codebamlss.frame()</a> uses function <a href="#">model.matrix</a> to construct the response matrix from levels. If the response is a factor ytype == "integer" will create an integer response.                                                                                                                                |
| scale.x          | Logical, should the model matrices of the linear parts be scaled?                                                                                                                                                                                                                                                                                                                                                                     |
| scale.d          | Logical, should the numeric variables in the model frame be scaled?                                                                                                                                                                                                                                                                                                                                                                   |
| ...              | Arguments passed to function <a href="#">smooth.construct.bamlss.frame</a> .                                                                                                                                                                                                                                                                                                                                                          |

## Details

The function parses the data, the formula or the extended `bamlss.formula` as well as the `bamlss.family` into a model frame like object, the `bamlss.frame`. This object holds all necessary model matrices and information that is needed for model fitting engines. Per default, all package `mgcv` smooth term constructor functions like `s`, `te`, `t2` and `ti` can be used (see also function `smooth.construct`), however, even special user defined constructors can be included, see the examples below.

Function `bamlss.frame()` uses function `model.matrix.bamlss.frame` to compute all design matrices for simple linear parts, all smooth terms are parsed with function `smooth.construct.bamlss.frame`.

It is also possible to create a "bamlss.frame" using hierarchical formulae, see the example below.

## Value

An list of class "bamlss.frame" with the following elements:

|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|--------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>call</code>        | The initial call.                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <code>model.frame</code> | The <code>model.frame</code> used to compute all design matrices.                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <code>formula</code>     | The <code>bamlss.formula</code> .                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <code>family</code>      | The <code>bamlss.family</code> object.                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <code>terms</code>       | The <code>terms.bamlss</code> object.                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <code>x</code>           | A named list, the elements correspond to the parameters that are specified within the <code>bamlss.family</code> object. For each parameter the corresponding formula, a <code>fake.formula</code> only holding the covariate names, a <code>terms</code> object, a <code>model.matrix</code> for the linear part and a list <code>smooth.construct</code> holding all information for smooth terms as returned from function <code>link{smooth.construct.bamlss.frame}</code> is created. |
| <code>y</code>           | The response data.                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

## See Also

`bamlss`, `bamlss.formula`, `bamlss.family`, `smooth.construct.bamlss.frame`, `model.matrix.bamlss.frame`

## Examples

```
## Create a 'bamlss.frame'.
d <- GAMart()
f <- list(
  num ~ fac + s(x1) + s(x2) + te(lon, lat),
  sigma ~ id + s(x2) + s(x3)
)
bf <- bamlss.frame(f, data = d, family = "gaussian")

## Show parts of the 'bamlss.frame'.
print(bf)

## Categorical responses.
f <- list(
  cat ~ fac + s(x1) + s(x2)
)
```



```

bf <- bamlss.frame(f, data = d, family = "multinomial", reference = "low")
print(bf)

## The response is a matrix per default.
head(bf$y)

## 0/1 responses.
d <- cbind(d, model.matrix(~ -1 + cat, data = d))

f <- list(
  catnone ~ fac + s(x1),
  catlow ~ s(x2),
  catmedium ~ s(x3)
)

bf <- bamlss.frame(f, data = d, family = "multinomial")
print(bf)

## Hierarchical structures.
f <- list(
  num ~ s(x1) + s(x2) + id,
  id ~ te(lon, lat),
  sigma ~ s(x1) + fac
)

bf <- bamlss.frame(f, data = d, family = "gaussian")
print(bf)

## Special model term constructors,
## set up "new" constructor function and eval
## with bamlss.frame().
s77 <- function(...) {
  sm <- s(...)
  sm$label <- paste("s77(", paste(sm$term, collapse = ", "), ")", sep = "")
  sm
}

f <- list(
  num ~ s77(x1) + s(x2) + id,
  sigma ~ s77(x1)
)

bf <- bamlss.frame(f, data = d, family = "gaussian", specials = "s77")
print(bf)
names(bf$x$mu$smooth.construct)

```

**Description**

Wrapper function for applying bootstrap estimation using gradient boosting.

**Usage**

```
## Bootstrap boosting.
bboost(..., data, type = 1, cores = 1,
        n = 2, prob = 0.623, fmstop = NULL,
        trace = TRUE, drop = FALSE, replace = FALSE)

## Plotting function.
bboost_plot(object, col = NULL)

## Predict method.
## S3 method for class 'bboost'
predict(object, newdata, ..., cores = 1, pfun = NULL)
```

**Arguments**

|         |                                                                                                                                                                                                                                                                                                                                                                                                |
|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ...     | Arguments passed to <a href="#">bamlss</a> and <a href="#">predict.bamlss</a> .                                                                                                                                                                                                                                                                                                                |
| data    | The data frame to be used for modeling.                                                                                                                                                                                                                                                                                                                                                        |
| type    | Type of algorithm, type = 1 uses all observations and samples with replacement, type = 2 uses only a fraction specified in prob and samples with replacement.                                                                                                                                                                                                                                  |
| cores   | The number of cores to be used.                                                                                                                                                                                                                                                                                                                                                                |
| n       | The number of bootstrap iterations.                                                                                                                                                                                                                                                                                                                                                            |
| prob    | The fraction that should be used to fit the model in each bootstrap iteration.                                                                                                                                                                                                                                                                                                                 |
| fmstop  | The function that should return the optimum stopping iteration. The function must have two arguments: (1) the model end (2) the data. The function must return a list with two named arguments: (1) "mstop" the optimum stopping iteration and (2) a vector of the objective criterion that should be evaluated by the hold out sample data during each bootstrap iteration. See the examples. |
| trace   | Prints out the current state of the bootstrap algorithm.                                                                                                                                                                                                                                                                                                                                       |
| drop    | Should only the best set of parameters be saved?                                                                                                                                                                                                                                                                                                                                               |
| replace | Sampling with replacement, or sampling ceiling(nobs * prob) rows of the data for fitting the n models.                                                                                                                                                                                                                                                                                         |
| object  | The "bboost" object used for prediction and plotting.                                                                                                                                                                                                                                                                                                                                          |
| col     | The color that should be used for plotting.                                                                                                                                                                                                                                                                                                                                                    |
| newdata | The data frame predictions should be made for.                                                                                                                                                                                                                                                                                                                                                 |
| pfun    | The prediction function that should be used, for example <a href="#">predictn</a> could be used, too. Note that this is experimental.                                                                                                                                                                                                                                                          |

**Value**

A list of [bamlss](#) objects.

**See Also**

[bamfss](#), [boost](#), [lasso](#), [BayesX](#)

**Examples**

```
## Not run: ## Simulate data.
set.seed(123)
d <- GAMart()

## Estimate model.
f <- num ~ s(x1) + s(x2) + s(x3) + s(lon,lat)

## Function for evaluation of hold out sample
## criterion to find the optimum mstop.
fmstop <- function(model, data) {
  p <- predict(model, newdata = data, model = "mu")
  mse <- NULL
  for(i in 1:nrow(model$parameters))
    mse <- c(mse, mean((data$num - p[, i])^2))
  list("MSE" = mse, "mstop" = which.min(mse))
}

## Bootstrap boosted models.
b <- bboost(f, data = d, n = 50, cores = 3, fmstop = fmstop)

## Plot hold out sample MSE.
bboost_plot(b)

## Predict for each bootstrap sample.
nd <- data.frame("x2" = seq(0, 1, length = 100))
p <- predict(b, newdata = nd, model = "mu", term = "x2")
plot2d(p ~ x2, data = nd)

## End(Not run)
```

---

 boost2

*Some Shortcuts*


---

**Description**

Some simple shortcuts to model fitting engines.

**Usage**

```
## BayesX.
bayesx2(...)

## Gradient boosting.
boost2(...)
```

```
## Lasso.  
lasso2(...)
```

### Arguments

... Arguments passed to [bamlss](#) and [predict.bamlss](#).

### Value

A `bamlss` object.

### See Also

[bamlss](#), [boost](#), [lasso](#), [BayesX](#)

### Examples

```
## Not run: ## Simulate data.  
set.seed(123)  
d <- GAMart()  
  
## Estimate model.  
f <- num ~ s(x1) + s(x2) + s(x3) + s(lon,lat)  
  
## Boosted model.  
b <- boost2(f, data = d)  
  
## Plot estimated effects.  
plot(b)  
  
## End(Not run)
```

---

c95

*Compute 95% Credible Interval and Mean*

---

### Description

Small helper function that computes the 2.5% and 97.5% quantiles and the mean of a vector. Useful for example when using function [predict.bamlss](#).

### Usage

```
c95(x)
```

### Arguments

x A numeric vector.

**See Also**

[predict.bamlss](#), [coef.bamlss](#)

**Examples**

```
x <- rnorm(100)
c95(x)

## Not run: ## Example computing predictions.
set.seed(123)
d <- data.frame("x" = seq(-3, 3, length = 30))
d$y <- sin(d$x) + rnorm(30, sd = 0.3)

## Estimate model and compute predictions.
## with c95().
b <- bamlss(y ~ s(x), data = d)
p <- predict(b, model = "mu", FUN = c95)
plot(d)
matplot(d$x, p, type = "l", lty = c(2, 1, 2),
        col = "black", add = TRUE)

## Example extracting coefficients.
coef(b, FUN = c95)

## End(Not run)
```

---

coef.bamlss

*Extract BAMLSS Coefficients*


---

**Description**

Methods to extract coefficients of fitted [bamlss](#) objects, either coefficients returned from optimizer functions, or samples from a sampler functions.

Method `confint.bamlss()` produces credible intervals or parameter samples using quantiles.

**Usage**

```
## S3 method for class 'bamlss'
coef(object, model = NULL, term = NULL,
      FUN = NULL, parameters = NULL,
      pterms = TRUE, sterms = TRUE,
      hyper.parameters = TRUE, list = FALSE,
      full.names = TRUE, rescale = FALSE, ...)

## S3 method for class 'bamlss'
confint(object, parm, level = 0.95,
        model = NULL, pterms = TRUE, sterms = FALSE,
        full.names = FALSE, hyper.parameters = FALSE, ...)
```

**Arguments**

|                  |                                                                                                                           |
|------------------|---------------------------------------------------------------------------------------------------------------------------|
| object           | An object of class "bamlss"                                                                                               |
| model            | Character or integer. For which model should coefficients be extracted?                                                   |
| term             | Character or integer. For which term should coefficients be extracted?                                                    |
| FUN              | A function that is applied on the parameter samples.                                                                      |
| parameters       | If is set to TRUE, additionally adds estimated parameters returned from an optimizer function (if available).             |
| pterms           | Should coefficients of parametric terms be included?                                                                      |
| sterms           | Should coefficients of smooths terms be included?                                                                         |
| hyper.parameters | For smooth terms, should hyper parameters such as smoothing variances be included?                                        |
| list             | Should the returned object have a list structure for each distribution parameter?                                         |
| full.names       | Should full names be assigned, indicating whether a term is parametric "p" or smooth "s".                                 |
| rescale          | Should parameters of the linear parts be rescaled if the scale.d argument in <a href="#">bamlss.frame</a> is set to TRUE. |
| parm             | Character or integer. For which term should coefficients intervals be extracted?                                          |
| level            | The credible level which defines the lower and upper quantiles that should be computed from the samples.                  |
| ...              | Arguments to be passed to FUN and function <a href="#">samples</a> .                                                      |

**Value**

Depending on argument `list` and the number of distributional parameters, either a `list` or `vector/matrix` of model coefficients.

**See Also**

[bamlss](#).

**Examples**

```
## Not run: ## Simulate data.
d <- GAMart()

## Model formula.
f <- list(
  num ~ s(x1) + s(x2) + s(x3),
  sigma ~ s(x1) + s(x2) + s(x3)
)

## Estimate model.
b <- bamlss(f, data = d)

## Extract coefficients based on MCMC samples.
```

```

coef(b)

## Now only the mean.
coef(b, FUN = mean)

## As list without the full names.
coef(b, FUN = mean, list = TRUE, full.names = FALSE)

## Coefficients only for "mu".
coef(b, model = "mu")

## And "s(x2)".
coef(b, model = "mu", term = "s(x2)")

## With optimizer parameters.
coef(b, model = "mu", term = "s(x2)", parameters = TRUE)

## Only parameteric part.
coef(b, sterms = FALSE, hyper.parameters = FALSE)

## For sigma.
coef(b, model = "sigma", sterms = FALSE,
      hyper.parameters = FALSE)

## 95 perc. credible interval based on samples.
confint(b)

## End(Not run)

```

---

colorlegend

*Plot a Color Legend*


---

## Description

Function to generate a color legend, the legend may be added to an existing plot or drawn in a separate plotting window.

## Usage

```

colorlegend(color = NULL, ncol = NULL, x = NULL, breaks = NULL,
            pos = "center", shift = 0.02, side.legend = 1L, side.ticks = 1L,
            range = NULL, lrange = NULL, width = 0.25, height = 0.05,
            scale = TRUE, xlim = NULL, ylim = NULL, plot = NULL, full = FALSE,
            add = FALSE, col.border = "black", lty.border = 1L, lwd.border = 1L,
            ticks = TRUE, at = NULL, col.ticks = "black", lwd.ticks = 1L,
            lty.ticks = 1L, length.ticks = 0.3, labels = NULL,
            distance.labels = 0, col.labels = "black", cex.labels = 1L,
            digits = 2L, swap = FALSE, symmetric = TRUE, xpd = NULL,
            title = NULL, side.title = 2, shift.title = c(0, 0),
            cex.title = 1, ...)

```

**Arguments**

|             |                                                                                                                                                                                                                                                                                                                                                                                        |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| color       | Character, integer. The colors for the legend, may also be a function, e.g. <code>colors = heat.colors</code> .                                                                                                                                                                                                                                                                        |
| ncol        | Integer, the number of different colors that should be generated if color is a function.                                                                                                                                                                                                                                                                                               |
| x           | Numeric, values for which the color legend should be drawn.                                                                                                                                                                                                                                                                                                                            |
| breaks      | Numeric, a set of breakpoints for the colors: must give one more breakpoint than ncol.                                                                                                                                                                                                                                                                                                 |
| pos         | Character, numeric. The position of the legend. Either a numeric vector, e.g. <code>pos = c(0.1, 0.2)</code> will add the legend at the 10% point in the x-direction and at the 20% point in the y-direction of the plotting window, may also be negative, or one of the following: "bottomleft", "topleft", "topright", "bottomright", "left", "right", "top", "bottom" and "center". |
| shift       | Numeric, if argument pos is a character, shift determines the distance of the legend from the plotting box.                                                                                                                                                                                                                                                                            |
| side.legend | Integer, if set to 2 the legend will be flipped by 90 degrees.                                                                                                                                                                                                                                                                                                                         |
| side.ticks  | Integer, if set to 2, the ticks and labels will be on the opposite site of the legend.                                                                                                                                                                                                                                                                                                 |
| range       | Numeric, specifies a range for x values for which the legend should be drawn.                                                                                                                                                                                                                                                                                                          |
| lrange      | Numeric, specifies the range of legend.                                                                                                                                                                                                                                                                                                                                                |
| width       | Numeric, the width of the legend, if <code>scale = TRUE</code> the width is proportional to the x-limits of the plotting window.                                                                                                                                                                                                                                                       |
| height      | Numeric, the height of the legend, if <code>scale = TRUE</code> the height is proportional to the y-limits of the plotting window.                                                                                                                                                                                                                                                     |
| scale       | Logical, if set to TRUE, the width and height of the legend will be calculated proportional to the x- and y-limits of the plotting window.                                                                                                                                                                                                                                             |
| xlim        | Numeric, the x-limits of the plotting window the legend should be added for, numeric vector, e.g., returned from function <a href="#">range</a> .                                                                                                                                                                                                                                      |
| ylim        | Numeric, the y-limits of the plotting window the legend should be added for, numeric vector, e.g., returned from function <a href="#">range</a> .                                                                                                                                                                                                                                      |
| plot        | Logical, if set to TRUE, the legend will be drawn in a separate plotting window.                                                                                                                                                                                                                                                                                                       |
| full        | Logical, if set to TRUE, the legend will be drawn using the full window range.                                                                                                                                                                                                                                                                                                         |
| add         | Logical, if set to TRUE, the legend will be added to an existing plot.                                                                                                                                                                                                                                                                                                                 |
| col.border  | The color of the surrounding border line of the legend.                                                                                                                                                                                                                                                                                                                                |
| lty.border  | The line type of the surrounding border line of the legend.                                                                                                                                                                                                                                                                                                                            |
| lwd.border  | The line width of the surrounding border line of the legend.                                                                                                                                                                                                                                                                                                                           |
| ticks       | Logical, if set to TRUE, ticks will be added to the legend.                                                                                                                                                                                                                                                                                                                            |
| at          | Numeric, specifies at which locations ticks and labels should be added.                                                                                                                                                                                                                                                                                                                |
| col.ticks   | The colors of the ticks.                                                                                                                                                                                                                                                                                                                                                               |
| lwd.ticks   | The line width of the ticks.                                                                                                                                                                                                                                                                                                                                                           |
| lty.ticks   | The line type of the ticks.                                                                                                                                                                                                                                                                                                                                                            |



|                 |                                                                                                                            |
|-----------------|----------------------------------------------------------------------------------------------------------------------------|
| length.ticks    | Numeric, the length of the ticks as percentage of the height or width of the colorlegend.                                  |
| labels          | Character, specifies labels that should be added to the ticks.                                                             |
| distance.labels | Numeric, the distance of the labels to the ticks, proportional to the length of the ticks.                                 |
| col.labels      | The colors of the labels.                                                                                                  |
| cex.labels      | Text size of the labels.                                                                                                   |
| digits          | Integer, the decimal places if labels are numerical.                                                                       |
| swap            | Logical, if set to TRUE colors will be represented in reverse order.                                                       |
| symmetric       | Logical, if set to TRUE, a symmetric legend will be drawn corresponding to the $\pm\max(\text{abs}(x))$ value.             |
| xpd             | Sets the xpd parameter in function <a href="#">par</a> .                                                                   |
| title           | Character, a title for the legend.                                                                                         |
| side.title      | Integer, 1 or 2. Specifies where the legend is placed, either on top if side.title = 1 or at the bottom if side.title = 2. |
| shift.title     | Numeric vector of length 2. Specifies a possible shift of the title in either x- or y-direction.                           |
| cex.title       | Text size for the title.                                                                                                   |
| ...             | Other graphical parameters to be passed to function <a href="#">text</a> .                                                 |

### Value

A named list with the colors generated, the breaks and the function map, which may be used for mapping of x values to the colors specified in argument colors, please see the examples below.

### Examples

```
## Play with colorlegend.
colorlegend()
colorlegend(side.legend = 2)
colorlegend(side.legend = 2, side.ticks = 2)
colorlegend(height = 2)
colorlegend(width = 1, height = 0.8, scale = FALSE,
  pos = c(0, 0.2), length.ticks = 0.5)
colorlegend(color = heat.colors, ncol = 9)
colorlegend(color = heat.colors, ncol = 9, swap = TRUE)
colorlegend(pos = "bottomleft")
colorlegend(pos = "topleft")
colorlegend(pos = "topright")
colorlegend(pos = "bottomright")

## Take x values for the color legend.
x <- runif(100, -2, 2)
colorlegend(color = diverge_hcl, x = x)
colorlegend(color = diverge_hcl, x = x, at = c(-1.5, 0, 1.5))
```

```

colorlegend(color = diverge_hcl, x = x, at = c(-1.5, 0, 1.5),
  labels = c("low", "middle", "high"))
colorlegend(color = rainbow_hcl, x = x, at = c(-1.5, 0, 1.5),
  labels = c("low", "middle", "high"), length.ticks = 1.5)
colorlegend(color = heat_hcl, x = x, at = c(-1.5, 0, 1.5),
  labels = c("low", "middle", "high"), length.ticks = 1.5,
  lwd.border = 2, lwd.ticks = 2, cex.labels = 1.5, font = 2)
colorlegend(color = topo.colors, x = x, at = c(-1.5, 0, 1.5),
  labels = c("low", "middle", "high"), length.ticks = 1.5,
  lwd.border = 2, lwd.ticks = 2, cex.labels = 1.5, font = 2,
  col.border = "green3", col.ticks = c(2, 5, 2),
  col.labels = c(6, 4, 3))
colorlegend(color = diverge_hsv, x = x, at = c(-1.5, 0, 1.5),
  labels = c("low", "middle", "high"), length.ticks = 1.5,
  lwd.border = 2, lwd.ticks = 2, cex.labels = 1.5, font = 2,
  col.border = "green3", col.ticks = c(2, 5, 2),
  col.labels = c(6, 4, 3), lty.border = 2, lty.ticks = c(2, 3, 2))
colorlegend(color = diverge_hsv, x = x, at = c(-1.5, 0, 1.5),
  labels = c("low", "middle", "high"), length.ticks = 1.5,
  lwd.border = 2, lwd.ticks = 2, cex.labels = 1.5, font = 2,
  col.border = "green3", col.ticks = c(2, 5, 2),
  col.labels = c(6, 4, 3), lty.border = 2, lty.ticks = c(2, 3, 2),
  ncol = 3)
colorlegend(color = c("red", "white", "red"), x = x, at = c(-1.5, 0, 1.5),
  labels = c("low", "middle", "high"), length.ticks = 1.5,
  lwd.border = 2, lwd.ticks = 2, cex.labels = 1.5, font = 2,
  col.border = "green3", col.ticks = c(2, 5, 2),
  col.labels = c(6, 4, 3), lty.border = 2, lty.ticks = c(2, 3, 2),
  ncol = 3, breaks = c(-2, -1, 1, 2))
colorlegend(color = diverge_hcl, x = x, range = c(-3, 3))
colorlegend(color = diverge_hcl, x = x, range = c(-3, 3), lrange = c(-6, 6))

## Combine plot with color legend.
n <- 100
x <- y <- seq(-3, 3, length.out = n)
z <- outer(sin(x), cos(x))
pal <- colorlegend(color = diverge_hcl, x = z, plot = FALSE)
op <- par(no.readonly = TRUE)
par(mar = c(4.1, 4.1, 1.1, 1.1))
layout(matrix(c(1, 2), nrow = 1), widths = c(1, 0.3))
image(x = x, y = y, z = z, col = pal$colors, breaks = pal$breaks)
par(mar = c(4.1, 0.1, 1.1, 3.1))
colorlegend(color = diverge_hcl, x = z, plot = TRUE, full = TRUE,
  side.legend = 2, side.ticks = 2)
par(op)

## Another example with different plot.
n <- 50
x <- sin(seq(-3, 3, length.out = n))
pal <- colorlegend(color = diverge_hcl, x = x, plot = FALSE)
op <- par(no.readonly = TRUE)

```

```

par(mar = c(7.1, 4.1, 1.1, 1.1))
barplot(x, border = "transparent", col = pal$map(x))
colorlegend(color = diverge_hcl, x = x, plot = FALSE, add = TRUE,
  xlim = c(0, 60), ylim = c(-1, 1), pos = c(0, -0.15), xpd = TRUE,
  scale = FALSE, width = 60, height = 0.15,
  at = seq(min(x), max(x), length.out = 9))
par(op)

```

---

 continue

*Continue Sampling*


---

### Description

This function takes a [bamlss](#) object which was created using a sampler function and continues sampling from the last state of the MCMC chain.

### Usage

```

continue(object, cores = NULL, combine = TRUE,
  sleep = NULL, results = TRUE, ...)

```

### Arguments

|         |                                                                                                                                                                                                                                                                                                                                  |
|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| object  | A <a href="#">bamlss</a> object which contains samples.                                                                                                                                                                                                                                                                          |
| cores   | An integer specifying the number of cores that should be used for the sampler function. This is based on function <a href="#">mclapply</a> of the <b>parallel</b> package.                                                                                                                                                       |
| combine | Should the new samples be combined with the old samples into one <a href="#">mcmc</a> matrix? Note that if <code>combine = FALSE</code> and the number of iterations differ from one sampling step to the other there will be an error since the start and end points in the samples <a href="#">mcmc</a> objects are different! |
| sleep   | Time the system should sleep before the next core is started.                                                                                                                                                                                                                                                                    |
| results | If a results function was used to create the <a href="#">bamlss</a> object, should the results function be applied using the new samples?                                                                                                                                                                                        |
| ...     | Arguments passed to the sampler function.                                                                                                                                                                                                                                                                                        |

### Value

A [bamlss](#) object.

### See Also

[bamlss](#)

## Examples

```
## Not run: ## Simulate and run model with MCMC.
set.seed(123)
d <- GAMart()
b <- bamlss(num ~ s(x1) + s(x2) + s(x3) + te(lon,lat), data = d)

## Continue sampling.
a <- continue(b)

## Plot all samples.
plot(a, which = "samples")

## End(Not run)
```

---

 cox\_predict

*Cox Model Prediction*


---

## Description

This function takes a fitted Cox model, i.e., a model estimated by [opt\\_Cox](#) or [sam\\_Cox](#) and computes predictions given a new data set or the original values. Survival probabilities are computed using numerical integration, therefore, computation may take some time. To avoid problems with computer memory, the prediction of survival probabilities can be split into chunks and computed parallel on different cores.

## Usage

```
cox_predict(object, newdata,
  type = c("link", "parameter", "probabilities"),
  FUN = function(x) { mean(x, na.rm = TRUE) },
  time = NULL, subdivisions = 100, cores = NULL,
  chunks = 1, verbose = FALSE, ...)
```

## Arguments

|         |                                                                                                                                                                                                                                                 |
|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| object  | A "bamlss" object as returned from function <a href="#">bamlss</a> using the optimizer <a href="#">opt_Cox</a> or sampler function <a href="#">sam_Cox</a> .                                                                                    |
| newdata | A data frame or list containing the values of the model covariates at which predictions are required. If missing newdata is the model.frame of the provided model.                                                                              |
| type    | Specifies the type of predictions that should be computed.                                                                                                                                                                                      |
| FUN     | A function that should be applied on each row of the samples of the additive predictor, parameter or probabilities. Per default the function computes means of samples, however, other functions like <a href="#">quantile</a> can be supplied. |
| time    | numeric, specifies the time for which survival probabilities should be computed if type = "probabilities". Note that this overwrites survival times that are supplied in argument newdata.                                                      |

|              |                                                                                                                                                                   |
|--------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| subdivisions | How many time points should be created for each individual.                                                                                                       |
| cores        | Specifies the number of cores that should be used for prediction. The problem is split into core chunks, each chunk is then processed by one core.                |
| chunks       | The number of chunks that should be processed sequentially on one core. This way memory problems can be avoided when computing survival times for large problems. |
| verbose      | Print progress information.                                                                                                                                       |
| ...          | Arguments passed to <a href="#">predict.bamlss</a> .                                                                                                              |

### Value

Depending on the type of function provided in argument FUN, a numeric vector or matrix.

### See Also

[sam\\_Cox](#), [cox\\_bamlss](#), [surv\\_transform](#), [simSurv](#), [bamlss](#), [predict.bamlss](#)

### Examples

```
## Not run: library("survival")
set.seed(123)

## Simulate survival data.
d <- simSurv(n = 500)

## Formula of the survival model, note
## that the baseline is given in the first formula by s(time).
f <- list(
  Surv(time, event) ~ s(time) + s(time, by = x3),
  gamma ~ s(x1) + s(x2)
)

## Cox model with continuous time.
## Note the the family object cox_bamlss() sets
## the default optimizer and sampler function!
## First, posterior mode estimates are computed
## using function opt_Cox(), afterwards the
## sampler sam_Cox() is started.
b <- bamlss(f, family = "cox", data = d)

## Predict survival probabilities P(T > t).
p <- predict(b, type = "probabilities",
  time = 3, subdivisions = 100, FUN = c95)

## End(Not run)
```

Crazy

*Crazy simulated data*

---

**Description**

This function creates simulated data based on a crazy function.

**Usage**

```
Crazy(n = 1000)
```

**Arguments**

n                    The number of observations to be simulated.

**Value**

A data frame with response y and covariate x.

**See Also**

[GAMart](#)

**Examples**

```
d <- Crazy(1000)
head(d)
plot(d)
```

---

CRPS*Continuous Rank Probability Score*

---

**Description**

The function computes the continuous rank probability score (CRPS). Note that the function uses numerical integration, for highly efficient computation please see the **scoringRules** package.

**Usage**

```
CRPS(object, newdata = NULL,
      interval = c(-Inf, Inf), FUN = mean,
      term = NULL, ...)
```

**Arguments**

|          |                                                                                                           |
|----------|-----------------------------------------------------------------------------------------------------------|
| object   | An object returned from <code>bamlss</code> .                                                             |
| newdata  | Optional new data that should be used for calculation.                                                    |
| interval | The interval that should be used for numerical integration                                                |
| FUN      | Function to be applied on the CRPS scores.                                                                |
| term     | If required, specify the model terms that should be used within the <code>predict.bamlss</code> function. |
| ...      | Arguments passed to function FUN.                                                                         |

**References**

Gneiting T, Raftery AE (2007). Strictly Proper Scoring Rules, Prediction, and Estimation." *Journal of the American Statistical Association*, 102(477), 359–378. doi: [10.1198/016214506000001437](https://doi.org/10.1198/016214506000001437)cd ..

Gneiting T, Balabdaoui F, Raftery AE (2007). Probabilistic Forecasts, Calibration and Sharpness. *Journal of the Royal Statistical Society B*, 69(2), 243–268. doi: [10.1111/j.14679868.2007.00587.x](https://doi.org/10.1111/j.14679868.2007.00587.x)

**Examples**

```
## Not run: ## Simulate data.
d <- GAMart()

## Model only including covariate x1.
b1 <- bamlss(num ~ s(x1), data = d)

## Now, also including x2 and x2.
b2 <- bamlss(num ~ s(x1) + s(x2) + s(x3), data = d)

## Compare using the CRPS score.
CRPS(b1)
CRPS(b2)

## End(Not run)
```

---

 DIC

*Deviance Information Criterion*


---

**Description**

Generic function returning the deviance information criterion (DIC) of a fitted model object.

**Usage**

```
DIC(object, ...)
```

**Arguments**

object            A fitted model object for which there exists a DIC method.  
 ...              Optionally more fitted model objects.

**Examples**

```
## Not run: d <- GAMart()
b1 <- bamlss(num ~ s(x1), data = d)
b2 <- bamlss(num ~ s(x1) + s(x2), data = d)
DIC(b1, b2)

## End(Not run)
```

dl.bamlss

*Deep Learning BAMLSS***Description**

This function interfaces **keras** infrastructures for high-level neural networks. The function can be used as a standalone model fitting engine such as [bamlss](#) or as an on top model engine to capture special features in the data that could not be captures by other model fitting engines.

**Usage**

```
## Deep learning bamlss.
dl.bamlss(object, optimizer = "adam",
  epochs = 30, batch_size = NULL,
  nlayers = 2, units = 100, activation = "sigmoid",
  l1 = NULL, l2 = NULL,
  verbose = TRUE, ...)

## Predict method.
## S3 method for class 'dl.bamlss'
predict(object, newdata,
  model = NULL, type = c("link", "parameter"),
  drop = TRUE, ...)
```

**Arguments**

object            An object of class "bamlss" or a [bamlss.formula](#).  
 optimizer        Character or call to optimizer functions to be used within [fit](#). For character, options are: "adam" "sgd", "rmsprop", "adagrad", "adadelta", "adamax", "adam". The default is [optimizer\\_rmsprop](#) with learning rate set to  $1e-04$ .  
 epochs           Number of times to iterate over the training data arrays, see [fit](#).  
 batch\_size       Number of samples per gradient update, see [fit](#).  
 nlayers          Number of hidden layers.



|            |                                                                                                                                                              |
|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| units      | Number of nodes per hidden layer, can be a vector.                                                                                                           |
| activation | Activation functions used for the hidden layers, can be a vector.                                                                                            |
| l1         | Shrinkage parameter for L1 penalty.                                                                                                                          |
| l2         | Shrinkage parameter for L2 penalty.                                                                                                                          |
| verbose    | Print information during runtime of the algorithm.                                                                                                           |
| newdata    | A <a href="#">list</a> or <a href="#">data.frame</a> that should be used for prediction.                                                                     |
| model      | Character or integer specifying for which distributional parameter predictions should be computed.                                                           |
| type       | If type = "link" the predictor of the corresponding model is returned. If type = "parameter" predictions on the distributional parameter scale are returned. |
| drop       | If predictions for only one model are returned, the list structure is dropped.                                                                               |
| ...        | For function <code>dl.boost()</code> , arguments passed to <a href="#">bamlss.frame</a> .                                                                    |

### Details

The default **keras** model is a sequential model with two hidden layers with "relu" activation function and 100 units in each layer. Between each layer is a dropout layer with 0.1 dropout rate.

### Value

For function `dl.bamlss()` an object of class "dl.bamlss". Note that extractor functions [fitted](#) and [residuals.bamlss](#) can be applied. For function `predict.dl.bamlss()` a list or vector of predicted values.

### WARNINGS

The BAMLSS deep learning infrastructure is still experimental!

### See Also

[bamlss.frame](#), [bamlss](#)

### Examples

```
## Not run: ## Simulate data.
set.seed(123)
n <- 300
x <- runif(n, -3, 3)
fsigma <- -2 + cos(x)
y <- sin(x) + rnorm(n, sd = exp(fsigma))

## Setup model formula.
f <- list(
  y ~ x,
  sigma ~ x
)

## Fit neural network.
```

```

library("keras")
b <- dl.bamlss(f, epochs = 2000)

## Plot estimated functions.
par(mfrow = c(1, 2))
plot(x, y)
plot2d(fitted(b)$mu ~ x, add = TRUE)
plot2d(fitted(b)$sigma ~ x,
  ylim = range(c(fitted(b)$sigma, fsigma)))
plot2d(fsigma ~ x, add = TRUE, col.lines = "red")

## Predict with newdata.
nd <- data.frame(x = seq(-6, 6, length = 100))
nd$p <- predict(b, newdata = nd, type = "link")

par(mfrow = c(1, 2))
plot(x, y, xlim = c(-6, 6), ylim = range(c(nd$p$mu, y)))
plot2d(p$mu ~ x, data = nd, add = TRUE)
plot2d(p$sigma ~ x, data = nd,
  ylim = range(c(nd$p$sigma, fsigma)))
plot2d(fsigma ~ x, add = TRUE, col.lines = "red")

## Plot quantile residuals.
e <- residuals(b)
plot(e)

## End(Not run)

```

---

engines

*Show Available Engines for a Family Object*


---

## Description

The function shows available optimizer and sampling engines for a given family object.

## Usage

```
engines(family, ...)
```

## Arguments

|        |                                            |
|--------|--------------------------------------------|
| family | A family object or the name of the family. |
| ...    | Further family objects or names.           |

## Examples

```
engines(gaussian_bamlss, "gamma", cox_bamlss)
```

**Description**

Family objects in **bamlss** specify the information that is needed for using (different) model fitting engines, e.g., the parameter names and corresponding link functions, the density function, derivatives of the log-likelihood w.r.t. the predictors, and so forth. The optimizer or sampler functions that are called by **bamlss** must know how much information is needed to interpret the model since the family objects are simply passed through. Family objects are also used for computing post-modeling statistics, e.g., for residual diagnostics or random number generation. See the details and examples.

**Usage**

```
## Family objects in bamlss:
ALD_bamlss(..., tau = 0.5, eps = 0.01)
beta_bamlss(...)
binomial_bamlss(link = "logit", ...)
cnorm_bamlss(...)
cox_bamlss(...)
dw_bamlss(...)
dirichlet_bamlss(...)
gaussian_bamlss(...)
gaussian2_bamlss(...)
Gaussian_bamlss(...)
gamma_bamlss(...)
logNN_bamlss(...)
multinomial_bamlss(...)
mvnorm_bamlss(k = 2, ...)
mvnormAR1_bamlss(k = 2, ...)
poisson_bamlss(...)
gpareto_bamlss(...)
glogis_bamlss(...)
AR1_bamlss(...)
beta1_bamlss(ar.start, ...)
nbinom_bamlss(...)
ztnbinom_bamlss(...)
lognormal_bamlss(...)
weibull_bamlss(...)
Sichel_bamlss(...)
GEV_bamlss(...)
gumbel_bamlss(...)
mix_bamlss(f1, f2, ...)

## Extractor functions:
## S3 method for class 'bamlss'
```

```
family(object, ...)
## S3 method for class 'bamlss.frame'
family(object, ...)
```

### Arguments

|          |                                                                                                                                                                                                                                                                                          |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| object   | An object of class "bamlss" or "bamlss.frame", see function <a href="#">bamlss</a> and <a href="#">bamlss.frame</a> .                                                                                                                                                                    |
| k        | The dimension of the multivariate normal. Note, if $k = 1$ function <code>gaussian_bamlss()</code> is called.                                                                                                                                                                            |
| ar.start | Logical vector of length equal to the number of rows of the full data set used for modeling. Must hold entries TRUE indicating the start of a time series of a section. If <code>ar.start = NULL</code> lagged residuals are computed by simple shifting. See also <a href="#">bam</a> . |
| link     | Possible link functions.                                                                                                                                                                                                                                                                 |
| tau      | The quantile the should be fitted.                                                                                                                                                                                                                                                       |
| eps      | Constant to be used for the approximation of the absolute function.                                                                                                                                                                                                                      |
| f1, f2   | A family of class "gamlss.family", see package <a href="#">gamlss.dist</a> .                                                                                                                                                                                                             |
| ...      | Arguments passed to functions that are called within the family object.                                                                                                                                                                                                                  |

### Details

The following lists the minimum requirements on a **bamlss** family object to be used with [bamlss](#) and [bamlss.frame](#):

- The family object must return a [list](#) of class "family.bamlss".
- The object must contain the family name as a character string.
- The object must contain the names of the parameters as a character string, as well as the corresponding link functions as character string.

For most optimizer and sampling functions at least the density function, including a `log` argument, should be provided. When using generic model fitting engines like [opt\\_bfit](#) or [sam\\_GMCMC](#), as well as for computing post-modeling statistics with function [samplestats](#), and others, it is assumed that the density function in a family object has the following arguments:

```
d(y, par, log = FALSE, ...)
```

where argument `y` is the response (possibly a matrix) and `par` is a named list holding the evaluated parameters of the distribution, e.g., using a normal distribution `par` has two elements, one for the mean `par$mu` and one for the standard deviation `par$sigma`. The dots argument is for passing special internally used objects, depending on the type of model this feature is usually not needed.

Similarly, for derivative based algorithms, e.g. using iteratively weighted least squares (IWLS, see function [opt\\_bfit](#), the family object holds derivative functions evaluating derivatives of the log-likelihood w.r.t. the predictors (or expectations of derivatives). For each parameter, these functions also hold the following arguments:

```
score(y, par, ...)
```

for computing the first derivative of the log-likelihood w.r.t. a predictor and

```
hess(y, par, ...)
```

for computing the negative second derivatives. Within the family object these functions are organized in a named list, see the examples below.

In addition, for the cumulative distribution function ( $p(y, \text{par}, \dots)$ ), for the quantile function ( $q(y, \text{par}, \dots)$ ) or for creating random numbers ( $r(n, \text{par}, \dots)$ ) the same structure is assumed. See, e.g., the code of function `gaussian.bamlss()`.

Some model fitting engines can initialize the distributional parameters which oftentimes leads to much faster convergence. The initialize functions are again organized within a named list, one entry for each parameter, similar to the score and hess functions, e.g., see the code of family object `gaussian.bamlss`.

Using function `bamlss`, `residuals.bamlss` and `predict.bamlss` the family objects may also specify the `transform()`, `optimizer()`, `sampler()`, `samplestats()`, `results()`, `residuals()` and `predict()` function that should be used with this family. See for example the setup of `cox_bamlss`.

For using specialized estimation engines like `sam_JAGS` it is recommended to supply any extra arguments needed by those engines with an additional list entry within the family object, e.g., using `gaussian_bamlss()` with `sam_JAGS` the family objects holds special details in an element named "bugs".

The examples below illustrate this setup. See also the code of the `bamlss` family functions.

## See Also

[bamlss](#), [bamlss.frame](#)

## Examples

```
## New family object for the normal distribution,
## can be used by function opt_bfit() and sam_GMCMC().
normal_bamlss <- function(...) {
  f <- list(
    "family" = "normal",
    "names" = c("mu", "sigma"),
    "links" = c("identity", "log"),
    "d" = function(y, par, log = FALSE) {
      dnorm(y, mean = par$mu, sd = par$sigma, log = log)
    },
    "score" = list(
      "mu" = function(y, par, ...) {
        drop((y - par$mu) / (par$sigma^2))
      },
      "sigma" = function(y, par, ...) {
        drop(-1 + (y - par$mu)^2 / (par$sigma^2))
      }
    ),
    "hess" = list(
      "mu" = function(y, par, ...) {
        drop(1 / (par$sigma^2))
      },
      "sigma" = function(y, par, ...) {
        rep(2, length(y))
      }
    )
  )
}
```

```

    }
  )
)
class(f) <- "family.bamlss"
return(f)
}

## Not run: ## Test on simulated data.
d <- GAMart()
b <- bamlss(num ~ s(x1) + s(x2) + s(x3),
  data = d, family = "normal")
plot(b)

## Compute the log-likelihood using the family object.
f <- family(b)
sum(f$d(y = d$num, par = f$map2par(fitted(b)), log = TRUE))

## For using JAGS() more details are needed.
norm4JAGS_bamlss <- function(...) {
  f <- normal_bamlss()
  f$bugs <- list(
    "dist" = "dnorm",
    "eta" = BUGSeta,
    "model" = BUGSmodel,
    "reparam" = c(sigma = "1 / sqrt(sigma)")
  )
  return(f)
}

## Now with opt_bfit() and sam_JAGS().
b <- bamlss(num ~ s(x1) + s(x2) + s(x3), data = d,
  optimizer = opt_bfit, sampler = sam_JAGS, family = "norm4JAGS")
plot(b)

## End(Not run)

```

---

fatalities

*Weekly Number of Fatalities in Austria*


---

### Description

This data set includes weekly fatalities in Austria from 2000 to 46 weeks in 2020. The data is taken from the Eurostat data base.

### Usage

```
data("fatalities")
```

**Format**

The fatalities data contains the following variables:

**num:** Integer, the number of fatalities.

**year:** Integer, the corresponding year fatalities are recorded.

**week:** Integer, the corresponding week fatalities are recorded..

**References**

Eurostat Database (2020). *Population and social conditions, demography and migration, mortality, weekly deaths, deaths by week and NUTS 3 region, Austria* <https://ec.europa.eu/eurostat/>

**Examples**

```
data("fatalities")
plot(num ~ week, data = fatalities)
```

---

|               |                             |
|---------------|-----------------------------|
| fitted.bamlss | <i>BAMLSS Fitted Values</i> |
|---------------|-----------------------------|

---

**Description**

Function to compute fitted values for `bamlss` models. The function calls `predict.bamlss` to compute fitted values from samples.

**Usage**

```
## S3 method for class 'bamlss'
fitted(object, model = NULL, term = NULL,
        type = c("link", "parameter"), samples = TRUE,
        FUN = c95, nsamps = NULL, ...)
```

**Arguments**

|         |                                                                                                                                                                                                                                                                                                                                                                      |
|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| object  | An object of class "bamlss"                                                                                                                                                                                                                                                                                                                                          |
| model   | Character or integer, specifies the model for which fitted values should be computed.                                                                                                                                                                                                                                                                                |
| term    | Character or integer, specifies the model terms for which fitted values are required. Note that if <code>samples = TRUE</code> , e.g., <code>term = c("s(x1)", "x2")</code> will compute the combined fitted values $s(x1) + x2$ .                                                                                                                                   |
| type    | If <code>type = "link"</code> the predictor of the corresponding model is returned. If <code>type = "parameter"</code> fitted values on the distributional parameter scale are returned.                                                                                                                                                                             |
| samples | Should fitted values be computed using samples of parameters or estimated parameters as returned from optimizer functions (e.g., function <code>bfit</code> returns "fitted.values"). The former results in a call to <code>predict.bamlss</code> , the latter simply extracts the "fitted.values" of the <code>bamlss</code> object and is not model term specific. |

|        |                                                                                                                                                                                                                                                                                                                                                           |
|--------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| FUN    | A function that should be applied on the samples of predictors or parameters, depending on argument type.                                                                                                                                                                                                                                                 |
| nsamps | If the fitted <code>bamlss</code> object contains samples of parameters, computing fitted values may take quite some time. Therefore, to get a first feeling it can be useful to compute fitted values only based on <code>nsamps</code> samples, i.e., <code>nsamps</code> specifies the number of samples which are extracted on equidistant intervals. |
| ...    | Arguments passed to function <code>predict.bamlss</code> .                                                                                                                                                                                                                                                                                                |

**Value**

Depending on arguments `model`, `FUN` and the structure of the `bamlss` model, a list of fitted values or simple vectors or matrices of fitted values.

**See Also**

[bamlss](#), [predict.bamlss](#).

**Examples**

```
## Not run: ## Generate some data.
d <- GAMart()

## Model formula.
f <- list(
  num ~ s(x1) + s(x2) + s(x3) + te(lon,lat),
  sigma ~ s(x1) + s(x2) + s(x3) + te(lon,lat)
)

## Estimate model.
b <- bamlss(f, data = d)

## Fitted values returned from optimizer.
f1 <- fitted(b, model = "mu", samples = FALSE)

## Fitted values returned from sampler.
f2 <- fitted(b, model = "mu", samples = TRUE, FUN = mean)

plot(f1, f2)

## End(Not run)
```

**Description**

This function creates artificial GAM-type `data.frames`. The function is mainly used for testing purposes.



**Usage**

```
GAMart(n = 500, sd = 0.1, seed = FALSE,  
      ti = c("none", "vcm", "main", "both"))
```

**Arguments**

|      |                                                               |
|------|---------------------------------------------------------------|
| n    | The number of observations.                                   |
| sd   | Standard deviation of the normal errors.                      |
| seed | Sets the seed to 111.                                         |
| ti   | For tensor product interaction term, the type of interaction. |

**Examples**

```
d <- GAMart()  
head(d)  
  
## Not run: b <- bamlss(num ~ s(x1) + s(x2) + s(x3) + te(lon,lat), data = d)  
plot(b)  
  
## End(Not run)
```

---

gamlss\_distributions *Extract Distribution families of the **gamlss.dist** Package*

---

**Description**

The functions searches in the **gamlss.dist** namespace for available distributions. It returns a named list of faily functions which can be used with [bamlss](#).

**Usage**

```
gamlss_distributions(type = c("continuous", "discrete"))
```

**Arguments**

|      |                                                                |
|------|----------------------------------------------------------------|
| type | Character specifying the type of distribution to be extracted. |
|------|----------------------------------------------------------------|

**See Also**

[bamlss](#)

**Examples**

```
## Not run:  
dists <- gamlss_distributions(type = "continuous")  
print(dists)  
  
## End(Not run)
```

---

GEFCom2014

*GEFCom2014 Electricity Load Data*

---

### Description

This data set is a subset of the electricity load data of the GEFCom2014 challenge. The full data is published in the Appendix of Hong T. et al. (2016).

### Usage

```
data("GEFCom2014")
```

### Format

The GEFCom2014 contains the following variables:

**date** The date of recording.

**load** The corresponding electricity load.

### References

Hong T., Pinson P, Fan S., Zareipour H., Troccoli A., and Hyndman R.J. (2016). Electric load forecasting, Electricity price forecasting, Wind power forecasting, Solar power forecasting, Probabilistic forecasting, Forecasting competition. *International Journal of Forecasting*, **32**(3), 896–913. doi: [10.1016/j.ijforecast.2016.02.001](https://doi.org/10.1016/j.ijforecast.2016.02.001)

### Examples

```
data("GEFCom2014", package = "bamlss")
GEFCom2014$yday <- as.POSIXlt(GEFCom2014$date)$yday
plot(load ~ yday, data = GEFCom2014)
```

---

gF

*Get a BAMLSS Family*

---

### Description

Function to get a `family.bamlss` object to be used for fitting. The main purpose of this function is to ease the handling of extra arguments to the family object.

### Usage

```
gF(x, ...)
```

**Arguments**

`x` The name of the `family.bamlss` without the ".bamlss" extension.  
`...` Arguments passed to the family object.

**Value**

A `family.bamlss` object.

**See Also**

`family.bamlss`.

**Examples**

```
f <- gF(gaussian)
print(f)
```

---

Golf

*Prices of Used Cars Data*

---

**Description**

This dataset is taken from the Regression Book and is about prices of used VW Golf cars.

**Usage**

```
data("Golf")
```

**Format**

The Golf data contains the following variables:

**price:** Numeric, sale price in 1000 Euro.

**age:** Numeric, age of the car in month.

**kilometer:** Numeric, kilometer reading in 1000 kilometers.

**tia:** Numeric, month until the next TIA appointment (German TUEV).

**abs:** Factor, does the car have abs?

**sunroof:** Factor, does the car have a sunroof?

**References**

Fahrmeir, L., Kneib, T., Lang, S. and Marx, B. (2013). Regression - Models, Methods and Applications, Springer. <https://www.uni-goettingen.de/de/551357.html>.

**Examples**

```
data("Golf")
plot(price ~ age, data = Golf)
plot(price ~ kilometer, data = Golf)
```

---

|               |                                    |
|---------------|------------------------------------|
| homstart_data | <i>HOMSTART Precipitation Data</i> |
|---------------|------------------------------------|

---

### Description

This function downloads and compiles the HOMSTART-project data set. The data is downloaded from the Zentralanstalt fuer Meteorologie und Geodynamik (ZAMG, <http://www.zamg.ac.at>) and funded by the Austrian Climate Research Programme (ACRP) and is free for research purposes.

### Usage

```
homstart_data(dir = NULL, load = TRUE, tdir = NULL)
```

### Arguments

|      |                                                                           |
|------|---------------------------------------------------------------------------|
| dir  | The directory where the homstart.rda file should be stored.               |
| load | Should the homstart data be loaded?                                       |
| tdir | An optional temporary directory where all downloaded files are processed. |

### Value

A data frame containing the following variables:

|                        |                                                                                               |
|------------------------|-----------------------------------------------------------------------------------------------|
| raw                    | The daily precipitation observations.                                                         |
| cens                   | Precipitation observations censored at 0.                                                     |
| bin                    | Factor with levels "yes" or "no" indicating precipitation.                                    |
| cat                    | Factor with levels "none", "low", "medium" and "high" indicating the amount of precipitation. |
| trend                  | A numeric time trend                                                                          |
| month                  | Month of of the observation.                                                                  |
| year                   | Year of the observation.                                                                      |
| day                    | Day of the year.                                                                              |
| lon                    | The longitude coordinate of the corresponding meteorological station.                         |
| lat                    | The latitude coordinate of the corresponding meteorological station.                          |
| id                     | Factor, meteorological station identifier.                                                    |
| cos1, cos2, sin1, sin2 | Transformed time trend for harmonic regression.                                               |
| weekend                | Factor, with levels "yes" and "no" indication if the observation was measured on a weekend.   |
| elevation              | Numeric, the elevation of the meteorological station.                                         |

## References

Nemec J, Gruber C, Chimani B, Auer I (2012). Trends in extreme temperature indices in Austria based on a new homogenised dataset. *International Journal of Climatology*. DOI 10.1002/joc.3532.

Nemec J, Chimani B, Gruber C, Auer I (2011). Ein neuer Datensatz homogenisierter Tagesdaten. *OEGM Bulletin*, **1**, 19–20. [http://www.meteorologie.at/docs/OEGM\\_bulletin\\_2011\\_1.pdf](http://www.meteorologie.at/docs/OEGM_bulletin_2011_1.pdf)

Umlauf N, Mayr G, Messner J, Zeileis A (2012). Why does it always rain on me? A spatio-temporal analysis of precipitation in Austria. *Austrian Journal of Statistics*, **41**(1), 81–92. <http://www.stat.tugraz.at/AJS/ausg121/121Zeileis.pdf>

## Examples

```
## Not run: homstart_data(load = TRUE)
head(homstart)

## End(Not run)
```

---

 jm\_bamlss

*Fit Flexible Additive Joint Models*


---

## Description

Family object to fit a flexible additive joint model for longitudinal and survival data under a Bayesian approach as presented in Koehler et al. (2017a, b). All parts of the joint model can be specified as structured additive predictors. See the details and examples.

## Usage

```
## JM family object.
jm_bamlss(...)

## "bamlss.frame" transformer function
## to set up joint models.
jm_transform(x, y, data, terms, knots, formula, family, subdivisions = 25,
  timedependent = c("lambda", "mu", "alpha", "dalpha"), timevar = NULL,
  idvar = NULL, alpha = .Machine$double.eps, mu = NULL, sigma = NULL,
  sparse = TRUE, nonlinear = FALSE, edf_alt = FALSE, start_mu = NULL,
  k_mu = 6, ...)

## Posterior mode optimizing engine.
opt_JM(x, y, start = NULL, weights = NULL, offset = NULL,
  criterion = c("AICc", "BIC", "AIC"), maxit = c(100, 1),
  nu = c("lambda" = 0.1, "gamma" = 0.1, "mu" = 0.1, "sigma" = 0.1,
  "alpha" = 0.1, "dalpha" = 0.1),
  update.nu = FALSE, eps = 0.0001, alpha.eps = 0.001, ic.eps = 1e-08,
  nback = 40, verbose = TRUE, digits = 4, ...)
```

```

jm_mode(x, y, start = NULL, weights = NULL, offset = NULL,
        criterion = c("AICc", "BIC", "AIC"), maxit = c(100, 1),
        nu = c("lambda" = 0.1, "gamma" = 0.1, "mu" = 0.1, "sigma" = 0.1,
              "alpha" = 0.1, "dalpha" = 0.1),
        update.nu = FALSE, eps = 0.0001, alpha.eps = 0.001, ic.eps = 1e-08,
        nback = 40, verbose = TRUE, digits = 4, ...)

## Sampler function.
sam_JM(x, y, family, start = NULL, weights = NULL, offset = NULL,
       n.iter = 1200, burnin = 200, thin = 1, verbose = TRUE, digits = 4,
       step = 20, ...)

jm_mcmc(x, y, family, start = NULL, weights = NULL, offset = NULL,
       n.iter = 1200, burnin = 200, thin = 1, verbose = TRUE, digits = 4,
       step = 20, ...)

## Predict function, set to default in jm_bamlss().
jm_predict(object, newdata,
          type = c("link", "parameter", "probabilities", "cumhaz", "loglik"),
          dt, steps, id, FUN = function(x) { mean(x, na.rm = TRUE) },
          subdivisions = 100, cores = NULL, chunks = 1,
          verbose = FALSE, ...)

## Survival plot.
jm_survplot(object, id = 1, dt = NULL, steps = 10,
            points = TRUE, rug = !points)

```

## Arguments

|               |                                                                                                                                                                                                                                                                                                  |
|---------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| x             | The x list, as returned from function <code>bamlss.frame</code> (and transformed by function <code>jm_transform()</code> ), holding all model matrices and other information that is used for fitting the model.                                                                                 |
| y             | The model response, as returned from function <code>bamlss.frame</code> .                                                                                                                                                                                                                        |
| data          | A <code>data.frame</code> or <code>list</code> containing the model response variable(s) and covariates specified in the formula in long format. By default the variables are taken from <code>environment(formula)</code> : typically the environment from which <code>bamlss</code> is called. |
| terms         | The corresponding <code>terms.bamlss</code> object needed for processing.                                                                                                                                                                                                                        |
| knots         | An optional list containing user specified knots, see the documentation of function <code>gam</code> .                                                                                                                                                                                           |
| formula       | The corresponding <code>bamlss.formula</code> .                                                                                                                                                                                                                                                  |
| family        | The <code>bamlss.family</code> object.                                                                                                                                                                                                                                                           |
| subdivisions  | How many time points should be created for each individual.                                                                                                                                                                                                                                      |
| timedependent | A character vector specifying the names of parameters in x that are time-dependent. Time grid design matrices are only computed for these parameters.                                                                                                                                            |
| timevar       | A character specifying the name of the survival time variable in the data set.                                                                                                                                                                                                                   |

|           |                                                                                                                                                                                                                                                     |
|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| idvar     | Depending on the type of data set, this is the name of the variable specifying identifier of individuals.                                                                                                                                           |
| alpha     | Numeric, a starting value for the intercept of the association parameter alpha.                                                                                                                                                                     |
| mu        | Numeric, a starting value for the intercept of the mu parameter.                                                                                                                                                                                    |
| sigma     | Numeric, a starting value for the intercept of the sigma parameter.                                                                                                                                                                                 |
| sparse    | Logical, indicating if sparse matrix structures are used for updating and sampling of mu parameter model terms.                                                                                                                                     |
| nonlinear | Logical, indicating if association is nonlinear in mu. See Details on the different model specifications.                                                                                                                                           |
| edf_alt   | Logical, indicating if an alternative computation of estimated degrees of freedom for penalized model terms should be used.                                                                                                                         |
| start_mu  | Starting values for the computation of mu. For estimating associations which are nonlinear in mu, knot placement is based on these starting values which can improve stability.                                                                     |
| k_mu      | Number of knots for spline basis of association nonlinear in mu. Reducing this number improves stability of the estimation.                                                                                                                         |
| start     | A named numeric vector containing possible starting values, the names are based on function <a href="#">parameters</a> .                                                                                                                            |
| weights   | Currently not supported.                                                                                                                                                                                                                            |
| offset    | Currently not supported.                                                                                                                                                                                                                            |
| criterion | Information criterion to be used, e.g., for smoothing variance selection. Options are the corrected AIC "AICc" (see Details), the "BIC" and "AIC". Defaults to "AICc"?                                                                              |
| maxit     | Vector containing the maximum number of iterations for the backfitting algorithm with maxit[1] defining the iterations for the full model and maxit[2] the iterations within each predictor. maxit[2] defaults to 1 if only one value is specified. |
| nu        | Vector of step lengths for parameter updates of one Newton-Raphson update for each predictor of the joint model.                                                                                                                                    |
| update.nu | Should the updating step length be optimized in each iteration of the backfitting algorithm? Uses nu as starting value if set to TRUE.                                                                                                              |
| eps       | The relative convergence tolerance of the backfitting algorithm.                                                                                                                                                                                    |
| alpha.eps | The relative convergence tolerance of the backfitting algorithm for predictor alpha.                                                                                                                                                                |
| ic.eps    | The relative convergence tolerance of the information criterion used, e.g., for smoothing variance selection.                                                                                                                                       |
| nback     | For computing ic.eps, how many iterations back should be included when computing relative convergence tolerance of the information criterion.                                                                                                       |
| verbose   | Print information during runtime of the algorithm.                                                                                                                                                                                                  |
| digits    | Set the digits for printing when verbose = TRUE.                                                                                                                                                                                                    |
| n.iter    | the number of MCMC iterations.                                                                                                                                                                                                                      |

|         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| burnin  | the burn-in phase of the sampler, i.e., the number of starting samples that should be removed.                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| thin    | the thinning parameter for MCMC simulation. E.g., thin = 10 means, that only every 10th sampled parameter will be stored.                                                                                                                                                                                                                                                                                                                                                                                                                            |
| step    | How many times should algorithm runtime information be printed, divides n.iter.                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| object  | A "bamlss" object processed with the JM optimizer function opt_JM() and/or sampler function sam_JM() for which the survival plot should be created.                                                                                                                                                                                                                                                                                                                                                                                                  |
| newdata | Dataset for which to create predictions. Not needed for conditional survival probabilities.                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| type    | Character string indicating which type of predictions to compute. link returns estimates for all predictors with the respective link functions applied, "parameter" returns the estimates for all predictors, "probabilities" returns the survival probabilities conditional on the survival up to the last longitudinal measurement, and "cumhaz" return the cumulative hazard up to the survival time or for a time window after the last longitudinal measurement. If type is set to "loglik", the log-likelihood of the joint model is returned. |
| id      | Integer or character, that specifies the individual for which the plot should be created.                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| dt      | The time window after the last observed measurement for which predictions should be computed. The default is $0.4 * \max(\text{obstime})$ and obstime are the individual's longitudinal measurement times.                                                                                                                                                                                                                                                                                                                                           |
| steps   | Integer, the number of steps for which to evaluate the conditional survival probability up to dt.                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| FUN     | A function that should be applied on the samples of predictors or parameters, depending on argument type.                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| cores   | Specifies the number of cores that should be used for prediction. Note that this functionality is based on the <a href="#">parallel</a> package.                                                                                                                                                                                                                                                                                                                                                                                                     |
| chunks  | Should computations be split into chunks? Prediction is then processed sequentially.                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| points  | Should longitudinal observations be added to the plot.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| rug     | Should longitudinal observed time points be added on the x-axis to the plot.                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| ...     | Currently not used.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |

## Details

We refer to the papers of Koehler et al. (2017a, b) for details on the flexible additive joint model. In short, we model the hazard of subject  $i$  an event at time  $t$  as

$$h_i(t) = \exp[\eta_{\lambda i}(t) + \eta_{\gamma i} + \eta_{\alpha i}(\eta_{\mu i}(t), t)]$$

with predictor  $\eta_{\lambda}$  for all survival covariates that are time-varying or have a time-varying coefficient (including the log baseline hazard), predictor  $\eta_{\gamma}$  for baseline survival covariates, predictor  $\eta_{\alpha}$  representing the potentially time-varying or nonlinear association between the longitudinal marker  $\eta_{\mu}$  and the hazard. The longitudinal response  $y_{ij}$  at time points  $t_{ij}$  is modeled as

$$y_{ij} = \eta_{\mu i}(t_{ij}) + e_{ij}$$



with independent normal errors  $N(0, \exp[\eta_{\sigma i}(t_{ij})]^2)$ .

Each predictor  $\eta_{ki}$  is a structured additive predictor, i.e. a sum of functions of covariates  $\eta_{ki} = \sum_{m=1}^{M_k} f_{km}(\mathbf{x}_{ki})$ . Each of these functions can be modeled parametrically or using basis function evaluations from the smooth constructors in **mgcv** such as **s**, **te** and **ti** and can include smooth time-varying, random or spatial effects. For the Bayesian estimation of these effects we specify corresponding priors: For linear or parametric terms we use vague normal priors, smooth and random effect terms are regularized by placing generic multivariate normal priors on the coefficients and for anisotropic smooths, when multiple smoothing variance parameters are involved, more complex prior are in place (cf. Koehler et al., 2017a). We use inverse Gamma hyper-priors, i.e.  $IG(0.001, 0.001)$  to obtain an inverse Gamma full conditional for the variance parameters. We estimate the posterior mode by maximizing the log-posterior of the model using a Newton-Raphson procedure, the posterior mean is obtained via derivative-based Metropolis-Hastings sampling. We recommend to use posterior mode estimates for a quick model assessment. In order to draw correct inferences from the model, posterior mean estimates should be computed. We approximate integration in the survival part of the likelihood using trapezoidal rule. For posterior mode estimation.

A variety specifications of the association  $\eta_{\alpha i}(\eta_{\mu i}(t), t)$  are possible with an important distinction between associations which are nonlinear in  $\eta_{\mu}$  for `nonlinear = TRUE` (Koehler et al. 2017b) or linear where  $\eta_{\alpha i}(\eta_{\mu i}(t), t) = \eta_{\alpha i}(t)\eta_{\mu i}(t)$  for `nonlinear = FALSE` (Koehler et al. 2017a).

### Note

The indicator `nonlinear` for associations with are linear or nonlinear in  $\eta_{\mu}$  was named `interaction` in earlier versions stages of the development.

### References

Koehler M, Umlauf N, Beyerlein, A., Winkler, C. Ziegler, A.-G., Greven S (2017). Flexible Bayesian Additive Joint Models with an Application to Type 1 Diabetes Research. *Biometrical Journal*. doi: [10.1002/bimj.201600224](https://doi.org/10.1002/bimj.201600224)

Meike Koehler, Nikolaus Umlauf, and Sonja Greven (2018). Nonlinear association structures in flexible Bayesian additive joint models. *Statistics in Medicine*. doi: [10.1002/sim.7967](https://doi.org/10.1002/sim.7967)

### See Also

[bamlss](#), [bamlss.frame](#).

### Examples

```
## Not run:

set.seed(123)
## Simulate survival data
## with random intercepts/slopes and a linear effect of time,
## constant association alpha and no effect of the derivative
d <- simJM(nsub = 200, long_setting = "linear",
  alpha_setting = "constant",
  dalpha_setting = "zero", full = FALSE)

## Formula of the according joint model
```

```

f <- list(
  Surv2(survtime, event, obs = y) ~ s(survtime, bs = "ps"),
  gamma ~ s(x1, bs = "ps"),
  mu ~ obstime + s(id, bs = "re") +
    s(id, obstime, bs = "re"),
  sigma ~ 1,
  alpha ~ 1,
  dalpha ~ -1
)

## Joint model estimation
## jm_bamlss() sets the default optimizer and sampler function.
## First, posterior mode estimates are computed using function
## opt_JM(), afterwards the sampler sam_JM() is started.
b <- bamlss(f, data = d, family = "jm",
            timevar = "obstime", idvar = "id")

## Plot estimated effects.
plot(b)

## Predict event probabilities for two individuals
## at 12 time units after their last longitudinal measurement.
## The event probability is conditional on their survival
## up to their last observed measurement.
p <- predict(b, type = "probabilities", id = c(1, 2), dt = 12, FUN = c95)
print(p)

## Plot of survival probabilities and
## corresponding longitudinal effects
## for individual id.
jm_survplot(b, id = 3)
jm_survplot(b, id = 30)

## Simulate survival data
## with functional random intercepts and a nonlinear effect
## of time, time-varying association alpha and no effect
## of the derivative.
## Note: This specification is the simJM default.
d <- simJM(nsub = 200, full = FALSE)

## Formula of the according joint model
## number of knots for the smooth nonlinear effect of time
klong <- 8
f <- list(
  Surv2(survtime, event, obs = y) ~ s(survtime, bs = "ps"),
  gamma ~ s(x1, bs = "ps"),
  mu ~ ti(id, bs = "re") +
    ti(obstime, bs = "ps", k = klong) +
    ti(id, obstime, bs = c("re", "ps"),
      k = c(nlevels(d$id), klong)) +
    s(x2, bs = "ps"),
  sigma ~ 1,

```

```

    alpha ~ s(survtime, bs = "ps"),
    dalpha ~ -1
  )

  ## Estimating posterior mode only using opt_JM()
  b_mode <- bamlss(f, data = d, family = "jm",
    timevar = "obstime", idvar = "id",
    sampler = FALSE)

  ## Estimating posterior means using sam_JM()
  ## with starting values generated from posterior mode
  b_mean <- bamlss(f, data = d, family = "jm",
    timevar = "obstime", idvar = "id", optimizer = FALSE,
    start = parameters(b_mode), results = FALSE)

  ## Plot effects.
  plot(b_mean, model = "alpha")

  ## Simulate survival data
  ## with functional random intercepts and an association nonlinear in mu
  set.seed(234)
  d <- simJM(nsub = 300, long_setting = "functional", alpha_setting = "nonlinear",
    nonlinear = TRUE, full = FALSE, probmiss = 0.9)

  ## Calculate longitudinal model to obtain starting values for mu
  long_df <- 7
  f_start <- y ~ ti(id, bs = "re") + ti(obstime, bs = "ps", k = long_df) +
    ti(id, obstime, bs = c("re", "ps"), k = c(nlevels(d$id), long_df)) +
    s(x2, bs = "ps")
  b_start <- bamlss(f_start, data = d, sampler = FALSE)
  mu <- predict(b_start)$mu

  ## Fit joint model with nonlinear association (nonlinear = TRUE)
  f <- list(
    Surv2(survtime, event, obs = y) ~ s(survtime, bs = "ps"),
    gamma ~ x1,
    mu ~ ti(id, bs = "re") + ti(obstime, bs = "ps", k = long_df) +
      ti(id, obstime, bs = c("re", "ps"), k = c(nlevels(d$id), long_df)) +
      s(x2, bs = "ps"),
    sigma ~ 1,
    alpha ~ 1,
    dalpha ~ -1
  )
  b <- bamlss(f, data = d, family = "jm", timevar = "obstime", idvar = "id",
    nonlinear = TRUE, start_mu = mu,
    n.iter = 6000, burnin = 2000, thin = 2)

  plot(b)
  samplestats(b$samples)

  ## End(Not run)

```

---

 la *Lasso Smooth Constructor*


---

**Description**

Smooth constructors and optimizer for Lasso penalization with `bamlss`. The penalization is based on a Taylor series approximation of the Lasso penalty.

**Usage**

```
## Smooth constructor function.
la(formula, type = c("single", "multiple"), ...)

## Single Lasso smoothing parameter optimizer.
opt_lasso(x, y, start = NULL, adaptive = TRUE, lower = 0.001, upper = 1000,
  nlambda = 100, lambda = NULL, multiple = FALSE, verbose = TRUE,
  digits = 4, flush = TRUE, nu = NULL, stop.nu = NULL,
  ridge = .Machine$double.eps^0.5, zeromodel = NULL, ...)

lasso(x, y, start = NULL, adaptive = TRUE, lower = 0.001, upper = 1000,
  nlambda = 100, lambda = NULL, multiple = FALSE, verbose = TRUE,
  digits = 4, flush = TRUE, nu = NULL, stop.nu = NULL,
  ridge = .Machine$double.eps^0.5, zeromodel = NULL, ...)

## Lasso transformation function to set
## adaptive weights from an unpenalized model.
lasso_transform(x, zeromodel, nobs = NULL, ...)

## Plotting function for opt_lasso() optimizer.
lasso_plot(x, which = c("criterion", "parameters"),
  spar = TRUE, model = NULL, name = NULL, mstop = NULL,
  retrans = FALSE, color = NULL, show.lambda = TRUE,
  labels = NULL, digits = 2, ...)

## Extract optimum stopping iteration for opt_lasso() optimizer.
## Based on the minimum of the information criterion.
lasso_stop(x)

## Extract retransformed Lasso coefficients.
lasso_coef(x, ...)
```

**Arguments**

|         |                                                                                                        |
|---------|--------------------------------------------------------------------------------------------------------|
| formula | A formula like $\sim x_1 + x_2 + \dots + x_k$ of variables which should be penalized with Lasso.       |
| type    | Should one single penalty parameter be used or multiple parameters, one for each covariate in formula. |

|           |                                                                                                                                                                                                                                                                                                                                                                                                       |
|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| x         | For function <code>opt_lasso()</code> and <code>lasso_transform()</code> the x list, as returned from function <code>bamlss.frame</code> , holding all model matrices and other information that is used for fitting the model. For the plotting function and <code>lasso_stop()/lasso_coef()</code> the corresponding <code>bamlss</code> object fitted with the <code>opt_lasso()</code> optimizer. |
| y         | The model response, as returned from function <code>bamlss.frame</code> .                                                                                                                                                                                                                                                                                                                             |
| start     | A vector of starting values. Note, Lasso smoothing parameters will be dropped.                                                                                                                                                                                                                                                                                                                        |
| adaptive  | Should adaptive weights be used for fused Lasso terms?                                                                                                                                                                                                                                                                                                                                                |
| lower     | Numeric. The minimum lambda value.                                                                                                                                                                                                                                                                                                                                                                    |
| upper     | Numeric. The maximum lambda value.                                                                                                                                                                                                                                                                                                                                                                    |
| nlambda   | Integer. The number of smoothing parameters for which coefficients should be estimated, i.e., the vector of smoothing parameters is build up as a sequence from lower to upper with length nlambda.                                                                                                                                                                                                   |
| lambda    | Numeric. A sequence/vector of lambda parameters that should be used.                                                                                                                                                                                                                                                                                                                                  |
| multiple  | Logical. Should the lambda grid be expanded to search for multiple lambdas, one for each distributional parameter.                                                                                                                                                                                                                                                                                    |
| verbose   | Print information during runtime of the algorithm.                                                                                                                                                                                                                                                                                                                                                    |
| digits    | Set the digits for printing when verbose = TRUE. If the optimum lambda value is plotted, the number of decimal decimal places to be used within <code>lasso_plot()</code> .                                                                                                                                                                                                                           |
| flush     | use <code>flush.console</code> for displaying the current output in the console.                                                                                                                                                                                                                                                                                                                      |
| nu        | Numeric or logical. Defines the step length for parameter updating of a model term, useful when the algorithm encounters convergence problems. If nu = TRUE the step length parameter is optimized for each model term in each iteration of the backfitting algorithm.                                                                                                                                |
| stop.nu   | Integer. Should step length reduction be stopped after stop.nu iterations of the Lasso algorithm?                                                                                                                                                                                                                                                                                                     |
| ridge     | A ridge penalty parameter that should be used when finding adaptive weights, i.e., parameters from an unpenalized model. The ridge penalty is used to stabilize the estimation in complex models.                                                                                                                                                                                                     |
| zeromodel | A model containing the unpenalized parameters, e.g., for each <code>la()</code> terms one can place a simple ridge penalty with <code>la(x, ridge = TRUE, sp = 0.1)</code> . This way it is possible to find the unpenalized parameters that can be used as adaptive weights for fusion penalties.                                                                                                    |
| nobs      | Integer, number of observations of the data used for modeling. If not supplied nobs is taken from the number of rows from the model term design matrices.                                                                                                                                                                                                                                             |
| which     | Which of the two provided plots should be created, character or integer 1 and 2.                                                                                                                                                                                                                                                                                                                      |
| spar      | Should graphical parameters be set by the plotting function?                                                                                                                                                                                                                                                                                                                                          |
| model     | Character selecting for which model the plot should be created.                                                                                                                                                                                                                                                                                                                                       |
| name      | Character, the name of the coefficient group that should be plotted. Note that the string provided in name will be removed from the labels on the 4th axis.                                                                                                                                                                                                                                           |
| mstop     | Integer vector, defines the path length to be plotted.                                                                                                                                                                                                                                                                                                                                                |
| retrans   | Logical, should coefficients be re-transformed before plotting?                                                                                                                                                                                                                                                                                                                                       |

|             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| color       | Colors or color function that creates colors for the group paths.                                                                                                                                                                                                                                                                                                                                                                                                                            |
| show.lambda | Logical. Should the optimum value of the penalty parameter lambda be shown?                                                                                                                                                                                                                                                                                                                                                                                                                  |
| labels      | A character string of labels that should be used on the 4 axis.                                                                                                                                                                                                                                                                                                                                                                                                                              |
| ...         | Arguments passed to the subsequent smooth constructor function. lambda controls the starting value of the penalty parameter, const the constant that is added within the penalty approximation. Moreover, fuse = 1 enforces nominal fusion of categorical variables and fuse = 2 ordered fusion within la() Note that la() terms with and without fusion should not be mixed when using the opt_lasso() optimizer function. For the optimizer opt_lasso() arguments passed to function bfit. |

### Value

For function la(), similar to function s a simple smooth specification object.

For function opt\_lasso() a list containing the following objects:

|               |                                                                                                                             |
|---------------|-----------------------------------------------------------------------------------------------------------------------------|
| fitted.values | A named list of the fitted values based on the last lasso iteration of the modeled parameters of the selected distribution. |
| parameters    | A matrix, each row corresponds to the parameter values of one boosting iteration.                                           |
| lasso.stats   | A matrix containing information about the log-likelihood, log-posterior and the information criterion for each lambda.      |

### References

Andreas Groll, Julien Hambuckers, Thomas Kneib, and Nikolaus Umlauf (2019). Lasso-type penalization in the framework of generalized additive models for location, scale and shape. *Computational Statistics & Data Analysis*. doi: [10.1016/j.csda.2019.06.005](https://doi.org/10.1016/j.csda.2019.06.005)

Oelker Margreth-Ruth and Tutz Gerhard (2015). A uniform framework for combination of penalties in generalized structured models. *Adv Data Anal Classif*. doi: [10.1007/s116340150205y](https://doi.org/10.1007/s116340150205y)

### See Also

[s](#), [smooth.construct](#)

### Examples

```
## Not run: ## Simulated fusion Lasso example.
bmu <- c(0,0,0,2,2,2,4,4,4)
bsigma <- c(0,0,0,-2,-2,-2,-1,-1,-1)
id <- factor(sort(rep(1:length(bmu), length.out = 300)))

## Response.
set.seed(123)
y <- bmu[id] + rnorm(length(id), sd = exp(bsigma[id]))

## Estimate model:
## fuse=1 -> nominal fusion,
```

```

## fuse=2 -> ordinal fusion,
## first, unpenalized model to be used for adaptive fusion weights.
f <- list(y ~ la(id,fuse=2,fx=TRUE), sigma ~ la(id,fuse=1,fx=TRUE))
b0 <- bamlss(f, sampler = FALSE)

## Model with single lambda parameter.
f <- list(y ~ la(id,fuse=2), sigma ~ la(id,fuse=1))
b1 <- bamlss(f, sampler = FALSE, optimizer = opt_lasso,
  criterion = "BIC", zeromodel = b0)

## Plot information criterion and coefficient paths.
lasso_plot(b1, which = 1)
lasso_plot(b1, which = 2)
lasso_plot(b1, which = 2, model = "mu", name = "mu.s.la(id).id")
lasso_plot(b1, which = 2, model = "sigma", name = "sigma.s.la(id).id")

## Extract coefficients for optimum Lasso parameter.
coef(b1, mstop = lasso_stop(b1))

## Predict with optimum Lasso parameter.
p1 <- predict(b1, mstop = lasso_stop(b1))

## Full MCMC, needs lasso_transform() to assign the
## adaptive weights from unpenalized model b0.
b2 <- bamlss(f, optimizer = FALSE, transform = lasso_transform,
  zeromodel = b0, nobs = length(y), start = coef(b1, mstop = lasso_stop(b1)),
  n.iter = 4000, burnin = 1000)
summary(b2)
plot(b2)

ci <- confint(b2, model = "mu", pterms = FALSE, sterms = TRUE)
lasso_plot(b1, which = 2, model = "mu", name = "mu.s.la(id).id", spar = FALSE)
for(i in 1:8) {
  abline(h = ci[i, 1], lty = 2, col = "red")
  abline(h = ci[i, 2], lty = 2, col = "red")
}

## End(Not run)

```

**Description**

This smooth constructor implements simple linear effects. The columns of the design matrix are automatically scaled. The main advantage of this constructor is speed when used in the BAMLSS boosting algorithm [boost](#). Optionally, a ridge penalty can be added, please see the example.

**Usage**

```
## Linear smooth constructor.
lin(...)

## For mgcv.
## S3 method for class 'linear.smooth.spec'
smooth.construct(object, data, knots, ...)
```

**Arguments**

```
...           For function lin() a formula of the type  $\sim x_1+x_2+x_3$  that specifies the covariates
               that should be modeled.
object, data, knots
               See smooth.construct.
```

**Value**

Function `lin()`, similar to function `s` a simple smooth specification object.

**See Also**

[bamlss](#), [predict.bamlss](#), [bfit](#), [boost](#)

**Examples**

```
## Not run: ## Simulate data.
set.seed(123)
d <- GAMart()

## Estimate model.
f <- num ~ lin(~x1+x2+x3+fac,ridge=TRUE)

b <- bamlss(f, data = d)

summary(b)

## End(Not run)
```

**Description**

Provides the compiled dwelling fire data of London in 2015. The data is provided as a [SpatialPointsDataFrame](#) in object `LondonFire`. In addition the boundary and borough information is provided in objects `LondonBoundaries` and `LondonBoroughs`. Locations of all fire stations in London of 2015 are provided in object `LondonFStations`.



**Usage**

```
data("LondonFire")
```

**Format**

The LondonFire data contains the following variables:

**arrivaltime:** Numeric, the time after the emergency call until the first fire engine arrived.

**daytime:** Numeric, The time of day at which the emergency call was received.

**fsintens:** Numeric, the fire station intensity at the location of the fire scene. The intensity is measured using a kernel density estimate of the LondonFStations using the **spatstat** package.

**References**

London Fire (2015). London Fire Brigade Incident Records. *London Data Store*, UK Open Government Licence (OGL v2). <https://data.london.gov.uk/dataset/london-fire-brigade-incident-records>

London Boroughs/Boundaries (2015). Statistical GIS Boundary Files for London. *London Data Store*, UK Open Government Licence (OGL v2). <https://data.london.gov.uk/dataset/statistical-gis-boundary->

London Fire Stations (2015). *London Fire Brigade*, <https://www.london-fire.gov.uk/>. (old url <http://www.london-fire.gov.uk/A-ZFireStations.asp>)

Taylor BM (2016). Spatial Modelling of Emergency Service Response Times. *Journal of the Royal Statistical Society: Series A (Statistics in Society)*, **180**(2), 433–453. doi: [10.1111/rssa.12192](https://doi.org/10.1111/rssa.12192)

**Examples**

```
data("LondonFire")
plot(LondonFire, col = "red")
plot(LondonFStations, col = "blue", cex = 1.5, pch = 16, add = TRUE)
plot(LondonBoroughs, lwd = 0.5, add = TRUE)
plot(LondonBoundaries, add = TRUE, lwd = 1.5)
head(LondonFire@data)
```

---

model.frame.bamlss      *BAMLSS Model Frame*

---

**Description**

Extracts the model frame of a `bamlss` or `bamlss.frame` object.

**Usage**

```
## S3 method for class 'bamlss'
model.frame(formula, ...)

## S3 method for class 'bamlss.frame'
model.frame(formula, ...)
```

```
## Internal helper function for creating
## the model frame.
bamlss.model.frame(formula, data, family = gaussian_bamlss(),
  weights = NULL, subset = NULL, offset = NULL,
  na.action = na.omit, specials = NULL, contrasts.arg = NULL,
  drop.unused.levels = TRUE, ...)
```

## Arguments

|                    |                                                                                                                                                                                                       |
|--------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| formula            | An object of class "bamlss" or "bamlss.frame".                                                                                                                                                        |
| data               | A <a href="#">data.frame</a> or <a href="#">list</a> containing the model response variable(s) and covariates specified in the formula. By default the variables are taken from environment(formula). |
| family             | A <a href="#">bamlss.family</a> object, see function <a href="#">bamlss</a> .                                                                                                                         |
| weights            | Prior weights on the data.                                                                                                                                                                            |
| subset             | An optional vector specifying a subset of observations to be used in the fitting process.                                                                                                             |
| offset             | Can be used to supply model offsets for use in fitting.                                                                                                                                               |
| na.action          | A function which indicates what should happen when the data contain NA's. The default is set by the na.action setting of <a href="#">options</a> , and is <a href="#">na.omit</a> if set to NULL.     |
| specials           | Special function in formulas, see <a href="#">terms.object</a> .                                                                                                                                      |
| contrasts.arg      | An optional list. See the contrasts.arg of <a href="#">model.matrix.default</a> .                                                                                                                     |
| drop.unused.levels | Should factors have unused levels dropped?                                                                                                                                                            |
| ...                | Arguments to be passed to <a href="#">bamlss.model.frame()</a> and others.                                                                                                                            |

## Value

The [data.frame](#) containing the variables used for modeling with function [bamlss](#).

## See Also

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

## Examples

```
## Not run: ## Generate some data.
d <- GAMart()

## Model formula.
f <- list(
  log(pnum) ~ s(x1) + log(x2),
  sigma ~ s(x3)
)

## Estimate model.
```

```

b <- bamlss(f, data = d)

## Extract the model frame.
head(model.frame(b))

## End(Not run)

```

---

```
model.matrix.bamlss.frame
```

*Construct/Extract BAMLSS Design Matrices*

---

## Description

The function creates design (or model) matrices for BAMLSS, i.e., for each parameter of a [bamlss.family](#) object.

## Usage

```

## S3 method for class 'bamlss.frame'
model.matrix(object, data = NULL, model = NULL,
             drop = TRUE, scale.x = FALSE, ...)

## S3 method for class 'bamlss.formula'
model.matrix(object, data = NULL, model = NULL,
             drop = TRUE, scale.x = FALSE, ...)

## S3 method for class 'bamlss.terms'
model.matrix(object, data = NULL, model = NULL,
             drop = TRUE, scale.x = FALSE, ...)

```

## Arguments

|         |                                                                                                         |
|---------|---------------------------------------------------------------------------------------------------------|
| object  | A <a href="#">bamlss.frame</a> , <a href="#">bamlss.formula</a> or <a href="#">terms.bamlss</a> object. |
| data    | A data frame or list.                                                                                   |
| model   | Character or integer, specifies the model for which design matrices should be returned.                 |
| drop    | If model matrices for only one model are returned, the list structure is dropped.                       |
| scale.x | Logical, should the model matrices of the linear parts be scaled?                                       |
| ...     | Not used.                                                                                               |

## Value

Depending on the type of model a named list of model matrices or a single model matrix.

## See Also

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

**Examples**

```

## Generate some data.
d <- GAMart()

## Model formula.
f <- list(
  num ~ x1 + x2 + id,
  sigma ~ x3 + fac + lon + lat
)

## Create a "bamlss.frame".
bf <- bamlss.frame(f, data = d)

## Get the model matrices.
X <- model.matrix(bf)
head(X$sigma)

## Same with "bamlss.formula".
X <- model.matrix(bamlss.formula(f), data = d)
head(X$sigma)

```

**Description**

This smooth constructor implements single hidden layer neural networks.

**Usage**

```

## The neural network smooth constructor.
n(..., k = 10, type = 2)

## Initialize weights.
n.weights(nodes, k, r = NULL, s = NULL,
  type = c("sigmoid", "gauss", "softplus", "cos", "sin"),
  x = NULL, ...)

## Second weights initializer, internally calls n.weights.
make_weights(object, data, dropout = 0.2)

## Boosted neural net predictions.
predictn(object, newdata, model = NULL,
  mstop = NULL, type = c("link", "parameter"))

```

**Arguments**

|                           |                                                                                                                                                                                                                                                                                                                                                                                         |
|---------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ...                       | For function <code>n()</code> a formula of the type <code>~x1+x2+x3</code> that specifies the covariates that should be modeled by the neural network. For function <code>predictn()</code> , arguments to be passed to <code>predict.bamlss</code> .                                                                                                                                   |
| <code>k</code>            | For function <code>n()</code> , the number of hidden nodes of the network. Note that one can set an argument <code>split = TRUE</code> to split up the neural network into, e.g., <code>nsplit = 5</code> parts with <code>k</code> nodes each. For function <code>n.weights()</code> , argument <code>k</code> is the number of input variables of the network (number of covariates). |
| <code>type</code>         | Integer. Type 1 fits a complete network in each boosting iteration, <code>type = 2</code> selects the best fitting node in each boosting iteration. for function <code>n.weights()</code> , the type of activation function that should be used. For function <code>predictn()</code> , the type of prediction that should be computed.                                                 |
| <code>nodes</code>        | Number of nodes for each layer, i.e., can also be a vector.                                                                                                                                                                                                                                                                                                                             |
| <code>r, s</code>         | Parameters controlling the shape of the activation functions.                                                                                                                                                                                                                                                                                                                           |
| <code>x</code>            | A scaled covariate matrix, the data will be used to identify the range of the weights.                                                                                                                                                                                                                                                                                                  |
| <code>object, data</code> | See <code>smooth.construct</code> . For function <code>predictn()</code> , a boosted "bamlss" object.                                                                                                                                                                                                                                                                                   |
| <code>dropout</code>      | The fraction of inner weights that should be set to zero.                                                                                                                                                                                                                                                                                                                               |
| <code>newdata</code>      | The data frame that should be used for prediction.                                                                                                                                                                                                                                                                                                                                      |
| <code>model</code>        | For which parameter of the distribution predictions should be computed.                                                                                                                                                                                                                                                                                                                 |
| <code>mstop</code>        | The stopping iteration for which predictions should be computed. The default is to return a matrix of predictions, each column represents the prediction of one boosting iteration.                                                                                                                                                                                                     |

**Value**

Function `n()`, similar to function `s` a simple smooth specification object.

**See Also**

`bamlss`, `predict.bamlss`, `bfit`, `boost`

**Examples**

```
## ... coming soon ...!
```

---

neighbormatrix

*Compute a Neighborhood Matrix from Spatial Polygons*

---

**Description**

The function takes a `SpatialPolygonsDataFrame` and computes the neighbor penalty matrix that can be used to fit a Markov random field, e.g., using the smooth constructor `smooth.construct.mrf.smooth.spec`.

**Usage**

```
## Compute the neighborhood matrix.
neighbormatrix(x, type = c("boundary", "dist", "deLaunay", "knear"),
  k = 1, id = NULL, nb = FALSE, names = NULL, ...)

## Plot neighborhood structure.
plotneighbors(x, add = FALSE, ...)
```

**Arguments**

|       |                                                                                                                                                                                                                                                               |
|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| x     | An object of class "SpatialPolygons" or "SpatialPolygonsDataFrame".                                                                                                                                                                                           |
| type  | Which type of neighborhood structure should be used, "boundary" uses <a href="#">poly2nb</a> , "dist" uses function <a href="#">dnearneigh</a> , "deLaunay" uses function <a href="#">tri2nb</a> and option "knear" applies function <a href="#">knn2nb</a> . |
| k     | For type = "knear", specifies number of nearest neighbors.                                                                                                                                                                                                    |
| id    | An identifier variable for which the penalty matrix should be computed.                                                                                                                                                                                       |
| nb    | Should only the neighborhood object be returned.                                                                                                                                                                                                              |
| names | Specifies the column where the regions names are provided in the data slot in the "SpatialPolygonsDataFrame"                                                                                                                                                  |
| add   | Should the neighborhood structure be added to an existing plot?                                                                                                                                                                                               |
| ...   | Arguments to be passed to function <a href="#">poly2nb</a> , <a href="#">dnearneigh</a> , <a href="#">tri2nb</a> or <a href="#">knn2nb</a> .                                                                                                                  |

**See Also**

[smooth.construct.mrf.smooth.spec](#), [dnearneigh](#), [tri2nb](#), [knn2nb](#).

**Examples**

```
data("LondonFire")

## Compute polygon boundary based
## neighborhood matrix.
nm <- neighbormatrix(LondonBoroughs)
print(nm)

## Plot neighborhood structures.
plotneighbors(LondonBoroughs)
plotneighbors(LondonBoroughs, type = "deLaunay")
plotneighbors(LondonBoroughs, type = "dist", d1 = 0, d2 = 0.15)
```

---

|            |                              |
|------------|------------------------------|
| opt_bbfitt | <i>Batchwise Backfitting</i> |
|------------|------------------------------|

---

### Description

Batchwise backfitting estimation engine for GAMLSS using very large data sets.

### Usage

```
## Batchwise backfitting engine.
opt_bbfitt(x, y, family, shuffle = TRUE, start = NULL, offset = NULL,
  epochs = 1, nbatch = 10, verbose = TRUE, ...)

bbfitt(x, y, family, shuffle = TRUE, start = NULL, offset = NULL,
  epochs = 1, nbatch = 10, verbose = TRUE, ...)

## Parallel version.
opt_bbfittp(x, y, family, mc.cores = 1, ...)

## Loglik contribution plot.
contribplot(x, ...)
```

### Arguments

|          |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| x        | For function <code>bfitt()</code> the x list, as returned from function <code>bamlss.frame</code> , holding all model matrices and other information that is used for fitting the model. For the updating functions an object as returned from function <code>smooth.construct</code> or <code>smoothCon</code> . For function <code>contribplot()</code> , a "bamlss" object using <code>bbfitt()</code> with argument <code>select = TRUE</code> . |
| y        | The model response, as returned from function <code>bamlss.frame</code> .                                                                                                                                                                                                                                                                                                                                                                            |
| family   | A <b>bamlss</b> family object, see <code>family.bamlss</code> .                                                                                                                                                                                                                                                                                                                                                                                      |
| shuffle  | Should observations be shuffled?                                                                                                                                                                                                                                                                                                                                                                                                                     |
| start    | A named numeric vector containing possible starting values, the names are based on function <code>parameters</code> .                                                                                                                                                                                                                                                                                                                                |
| offset   | Can be used to supply model offsets for use in fitting, returned from function <code>bamlss.frame</code> .                                                                                                                                                                                                                                                                                                                                           |
| epochs   | For how many epochs should the algorithm run?                                                                                                                                                                                                                                                                                                                                                                                                        |
| nbatch   | Number of batches. Can also be a number between 0 and 1, i.e., determining the fraction of observations that should be used for fitting.                                                                                                                                                                                                                                                                                                             |
| verbose  | Print information during runtime of the algorithm.                                                                                                                                                                                                                                                                                                                                                                                                   |
| mc.cores | On how many cores should estimation be started?                                                                                                                                                                                                                                                                                                                                                                                                      |
| ...      | For <code>bbfittp()</code> all arguments to be passed to <code>bbfitt()</code> .                                                                                                                                                                                                                                                                                                                                                                     |

## Details

The algorithm uses batch-wise estimation of regression coefficients and smoothing variances. The smoothing variances are estimated on an hold-out batch. This way, models for very large data sets can be estimated. Note, the algorithm can work in combination with the **ff** and **ffbase** package, i.e., the entire data is never in the computer RAM. Therefore, the data can either be stored as comma separated file on disc or provided as "ffdf" data frame, see also the examples.

The optimizer functions use additional arguments:

- `batch_ids`. This argument can either be a list of indices specifying the batches that should be used for estimation, or a vector of length 2, where the first element specifies the number of observations that should be sampled for each batch and the second argument specifies the number of batches, see the example.
- `nu`, the step length control parameter. Defaults to `nu = 0.05`. If argument `slice = TRUE` then `nu = 1`.
- `loglik`, defaults to `loglik = FALSE`. If set to `loglik = TRUE` the "out-of-sample" log-likelihood is used for smoothing variance estimation.
- `aic`, defaults to `aic = FALSE`. If set to `aic = TRUE` the "out-of-sample" AIC is used for smoothing variance estimation.
- `eps_loglik`, defaults to `eps_loglik = 0.01`. This argument specifies the relative change in the "out-of-sample" log-likelihood that is needed such that a model term gets updated.
- `select`, defaults to `select = FALSE`. If set to `select = TRUE`, the algorithm only selects the model term with the largest contribution in the "out-of-sample" log-likelihood for updating in each iteration/batch.
- `always`, defaults to `always = FALSE`. If set to `always = TRUE` no log-likelihood contribution checks will be used and model terms are always updated.
- `K`, defaults to `K = 2`. This argument controls the penalty on the degrees of freedom in the computation of the AIC.
- `slice`, defaults to `slice = FALSE`. If set to `slice = TRUE`, slice sampling using the "out-of-sample" log-likelihood or AIC is used for smoothing variance estimation. Moreover, `always = TRUE`, `eps_loglik = -Inf` and `nu = 1`. If `slice` is an integer `n`, slice sampling is started after `n` iterations, before smoothing variances are optimized.

When using function `opt_bbfitt`, the parameter updates are stored as "mcmc" objects. In this case the traceplots can be visualized using `plot.bamlss`.

## Value

For function `opt_bbfitt()` a list containing the following objects:

|                            |                                                                                           |
|----------------------------|-------------------------------------------------------------------------------------------|
| <code>fitted.values</code> | A named list of the fitted values of the modeled parameters of the selected distribution. |
| <code>parameters</code>    | The estimated set regression coefficients and smoothing variances.                        |
| <code>shuffle</code>       | Logical                                                                                   |
| <code>runtime</code>       | The runtime of the algorithm.                                                             |



**See Also**[bamlss](#), [bfitt](#)**Examples**

```
## Not run: ## Simulate data.
set.seed(123)
d <- GAMart(n = 27000, sd = -1)

## Write data to disc.
tf <- tempdir()
write.table(d, file.path(tf, "d.raw"), quote = FALSE, row.names = FALSE, sep = ",")

## Model formula.
f <- list(
  num ~ s(x1,k=40) + s(x2,k=40) + s(x3,k=40) + te(lon,lat,k=10),
  sigma ~ s(x1,k=40) + s(x2,k=40) + s(x3,k=40) + te(lon,lat,k=10)
)

## Specify 50 batches with 1000 observations.
batch_ids <- c("nobs" = 1000, "nbatch" = 50)

## Note, can also be a list of indices, e.g.
## batch_ids <- lapply(1:50, function(i) { sample(1:nrow(d), size = 1000) })

## Different flavors:
## (1) Using "out-of-sample" aic for smoothing
## variance estimation. Update is only accepted
## if the "out-of-sample" log-likelihood is
## increased. If data is a filepath, the data set is
## read into R using package ff and model and
## design matrices are processed with ff. This may
## take some time depending on the size of the data.
set.seed(1)
b1 <- bamlss(f, data = file.path(tf, "d.raw"),
  sampler = FALSE, optimizer = opt_bbfitt,
  batch_ids = batch_ids, nu = 0.1, aic = TRUE, eps_loglik = -Inf,
  always = FALSE)

## Plot estimated effects.
plot(b1)

## Plot coefficient paths for x3 in mu.
pathplot(b1, name = "mu.s.s(x3).b")

## (2) Same but always update, this mimics the classic SGD.
## Note, for prediction only the last iteration is
## used in this case. To use more iterations use opt_bbfittp(),
## Then iterations are stored as "mcmc" object and we can
## predict using the burnin argment, e.g.,
## p <- predict(b2, model = "mu", burnin = 35)
set.seed(2)
```

```

b2 <- bamlss(f, data = file.path(tf, "d.raw"),
  sampler = FALSE, optimizer = opt_bbfitt,
  batch_ids = batch_ids, nu = 0.1, aic = TRUE, eps_loglik = -Inf,
  always = TRUE)

## Plot coefficient paths for x3 in mu.
pathplot(b2, name = "mu.s.s(x3).b")

## (3) Boosting type flavor, only update model term with
## the largest contribution in the "out-of-sample"
## log-likelihood. In this case, if edf = 0 during
## runtime of the algorithm, no model has an additional
## contribution and the algorithm converges. This
## behavior is controlled by argument eps_loglik, the
## higher eps_loglik, the more restrictive is the
## updating step.

## Initialize intercepts.
set.seed(0)
b0 <- bamlss(num ~ 1, data = d, sampler = FALSE, optimizer = opt_bbfitt,
  batch_ids = batch_ids, slice = TRUE)

## Compute starting values, remove the first
## 10 iterates and compute the mean of the
## remaining iterates.
start <- coef(b0, FUN = mean, burnin = 10)

## Start boosting, only update if change in
## "out-of-sample" log-likelihood is 0.1
## eps_loglik = 0.001.
set.seed(3)
b3 <- bamlss(f, data = d, sampler = FALSE, optimizer = opt_bbfitt,
  batch_ids = batch_ids, nu = 0.1, aic = TRUE, eps_loglik = 0.001,
  select = TRUE, always = FALSE, start = start)

## Plot log-likelihood contributions.
contribplot(b3)
## In this case, the algorithm did not converge,
## we need more iterations/batches.

## Note, prediction uses last iterate.
p3 <- predict(b3, model = "mu")

## (4) Use slice sampling under the "out-of-sample"
## log likelihood for estimation of smoothing
## variances. In this case model terms are always
## updated and parameter paths behave like a MCMC
## chain. Therefore, use opt_bbfitt(), which stores
## parameter paths as "mcmc" objects and we can
## inspect using traceplots. Note nu = 1 if
## slice = TRUE.
set.seed(4)
b4 <- bamlss(f, data = d, sampler = FALSE, optimizer = opt_bbfitt,

```

```

    batch_ids = batch_ids, aic = TRUE, slice = TRUE)

plot(b4)

## Plot parameter updates/samples.
plot(b4, which = "samples")

## Predict with burnin and compute mean
## prediction of the last 20 iterates.
p4 <- predict(b4, model = "mu", burnin = 30, FUN = mean)

## End(Not run)

```

---

opt\_bfit

*Fit BAMLSS with Backfitting*


---

## Description

This optimizer function is a generic tool for fitting BAMLSS using a backfitting algorithm. The backfitting procedure is based on iteratively weighted least squares (IWLS) for finding posterior mode estimates, however, the updating methods for model terms can be more general, see the details section. In addition, the default IWLS updating scheme implements optimum smoothing variance selection based on information criteria using a stepwise approach.

## Usage

```

## Optimizer functions:
opt_bfit(x, y, family, start = NULL, weights = NULL, offset = NULL,
  update = "iwls", criterion = c("AICc", "BIC", "AIC"),
  eps = .Machine$double.eps^0.25, maxit = 400,
  outer = NULL, inner = FALSE, mgcv = FALSE,
  verbose = TRUE, digits = 4, flush = TRUE,
  nu = TRUE, stop.nu = NULL, ...)

bfit(x, y, family, start = NULL, weights = NULL, offset = NULL,
  update = "iwls", criterion = c("AICc", "BIC", "AIC"),
  eps = .Machine$double.eps^0.25, maxit = 400,
  outer = NULL, inner = FALSE, mgcv = FALSE,
  verbose = TRUE, digits = 4, flush = TRUE,
  nu = TRUE, stop.nu = NULL, ...)

## Model term updating functions:
bfit_iwls(x, family, y, eta, id, weights, criterion, ...)
bfit_iwls_Matrix(x, family, y, eta, id, weights, criterion, ...)
bfit_lm(x, family, y, eta, id, weights, criterion, ...)
bfit_optim(x, family, y, eta, id, weights, criterion, ...)
bfit_glmnet(x, family, y, eta, id, weights, criterion, ...)

```

**Arguments**

|           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| x         | For function <code>opt_bfit()</code> the x list, as returned from function <code>bamlss.frame</code> , holding all model matrices and other information that is used for fitting the model. For the updating functions an object as returned from function <code>smooth.construct</code> or <code>smoothCon</code> .                                                                                                                                                                                                                                                                                                                                                                                                        |
| y         | The model response, as returned from function <code>bamlss.frame</code> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| family    | A <b>bamlss</b> family object, see <code>family.bamlss</code> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| start     | A named numeric vector containing possible starting values, the names are based on function <code>parameters</code> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| weights   | Prior weights on the data, as returned from function <code>bamlss.frame</code> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| offset    | Can be used to supply model offsets for use in fitting, returned from function <code>bamlss.frame</code> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| update    | Sets the updating function for model terms, e.g. for a term $s(x)$ in the model formula. Per default this is set to "iwlsl", a character pointing to the set of updating functions, see above. Other options are "optim" and "lm" etc., however, this is more experimental and should not be set by the user. Another option is to pass a full updating function which should be used for each model term, the structure of updating functions is described in the details below. Model terms may also have different updating functions, see the example section implementing a new model term constructor for Gompertz growth curves using this feature.                                                                  |
| criterion | Set the information criterion that should be used, e.g., for smoothing variance selection. Options are the corrected AIC "AICc", the "BIC" and "AIC".                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| eps       | The relative convergence tolerance of the backfitting algorithm.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| maxit     | The maximum number of iterations for the backfitting algorithm                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| outer     | Should the current working observations and weights be computed in one outer iteration, otherwise the working observations are computed anew for each model term updating step. The default will run one outer iteration first, afterwards model weights are computed for each term anew.                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| inner     | Should the model terms for one parameter of the modeled distribution be fully updated until convergence in an inner iteration, i.e., the algorithm waits until coefficients for the current distribution parameter do not change anymore before updating the next parameter.                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| mgcv      | Should the <b>mgcv</b> <code>gam</code> function be used for computing updates in an inner iteration with working observations provided in an outer iteration.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| verbose   | Print information during runtime of the algorithm.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| digits    | Set the digits for printing when <code>verbose = TRUE</code> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| flush     | use <code>flush.console</code> for displaying the current output in the console.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| nu        | Logical, numeric or NULL. Function <code>opt_bfit()</code> uses step length optimization of parameters when updating a model term, useful to encounter convergence problems of the algorithm. If <code>nu = TRUE</code> the step length parameter is optimized for each model term in each iteration of the backfitting algorithm. If <code>nu</code> is numeric, e.g. <code>nu = 1</code> , then <code>nu</code> is halved until an improvement in the log-posterior is obtained or <code>nu</code> is smaller than <code>.Machine\$double.eps</code> . If <code>nu = NULL</code> , no step length optimization is performed. Note, using very large data sets it is usually better to switch of step length optimization. |

|         |                                                                                                                                                                                                                                                                                                                                                                                                                      |
|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| stop.nu | Integer. Should step length reduction be stopped after stop.nu iterations of the backfitting algorithm?                                                                                                                                                                                                                                                                                                              |
| eta     | The current value of the predictors, provided as a named list, one list entry for each parameter. The names correspond to the parameter names in the family object, see <a href="#">family.bamlss</a> . E.g., when using the <a href="#">gaussian_bamlss</a> family object, the current values for the mean can be extracted by <code>eta\\$\mu</code> and for the standard deviation by <code>eta\\$\sigma</code> . |
| id      | Character, the name of the current parameter for which the model term should be updated.                                                                                                                                                                                                                                                                                                                             |
| ...     | For function <code>opt_bfit()</code> , arguments passed to function <a href="#">bamlss.engine.setup</a> . For updating functions, within the dots argument the actual iteration number of the backfitting algorithm, the actual total number of equivalent degrees of freedom <code>edf</code> and vectors <code>z</code> and <code>hess</code> only if argument <code>outer = TRUE</code> are provided.             |

## Details

This algorithm is based on iteratively weighted least squares (IWLS) for BAMLSS, i.e., a Newton-Raphson or Fisher scoring algorithm is applied, similar to Rigby~and~Stasinopoulos~(2005). The algorithm utilizes the chain rule for computing derivatives of the log-posterior w.r.t. regression coefficients, therefore, to compute the working observations and weights only the derivatives of the log-likelihood w.r.t. the predictors are required.

It is assumed that the provided family object holds functions for computing the first and second order derivatives of the log-likelihood w.r.t. the predictors. These Functions are provided within the named lists "score" and "hess" within the family object. See the documentation of [family.bamlss](#) and the code of the provided families, e.g. [gaussian\\_bamlss](#), for examples of the required structure.

The algorithm either updates each model term over all distributional parameters sequentially, or does a full update until convergence for model terms for one distributional parameter before updating the next parameter, see argument `inner`. Additionally, working observations and weights can be computed only once in an outer iteration.

Starting values of regression coefficients and smoothing variances can be supplied, moreover, if a family object holds functions for initializing the distributional parameters, see also [family.bamlss](#), starting values are based on the initialize functions.

The default updating function for model terms is based on IWLS, which is assigned by function [bamlss.engine.setup](#), however, special updating functions can be used. This is achieved by providing an updating function to argument `update`, which should be used for all model terms. Another option is to set the updating function within the `xt` argument of the `mgcv` smooth term constructor functions, see e.g. function `s`. If the `xt` list then holds an element named "update", which is a valid updating function, this updating function is used for the corresponding model term. This way it is possible to call different (special) updating functions for specific terms, e.g., that do not fit in the IWLS scheme. See the examples below. Note that this does not work if `mgcv = TRUE`, since the `gam` function assumes a strict linear representation of smooth terms.

A model term updating function has the following arguments:

```
update(x, family, y, eta, id, weights, criterion, ...)
```

Here `x` is an object as returned from function `smooth.construct` or `smoothCon`. The `x` object is preprocessed by function `bamlss.engine.setup`, i.e., an element called "state" is assigned. The state element represents the current state of the model term holding the current values of the parameters with corresponding fitted values, as well as equivalent degrees of freedom, see also the values that are returned by such functions below. The backfitting algorithm uses the state of a model term for generating updates of the parameters. Note that for special model terms the state list should already be provided within the call to the corresponding smooth constructor function, see the growth curve example below.

In addition, for special model terms the fitted values may not be computed by a linear combination of the design matrix and the coefficients. Therefore, the `x` object should hold an element named "fit.fun" which is a function for computing the fitted values. See also `smooth.construct.bamlss.frame` and `predict.bamlss` that use this setup. The arguments of fitting functions are

```
fit.fun(X,b,...)
```

where `X` is the design matrix and `b` is the vector of coefficients. Hence, for usual IWLS updating the fitted values are computed by `X %*% b`. For special terms like nonlinear growth curves this may not be the case, see the example below. The fitting functions are assigned by `bamlss.engine.setup`, unless the function is already provided after calling the constructor function `smooth.construct` or `smoothCon`. Note that the dots argument is usually not needed by the user.

The default updating function is `bfit_iwls()`. Function `bfit_iwls_Matrix()` uses the sparse matrix infrastructures of package **Matrix**. The **Matrix** package and `bfit_iwls_Matrix()` is used for model terms where the maximum number of non-zero entries in the design matrix is less than half of the total number of columns, if an additional argument `force.Matrix` is set to `TRUE` in the `opt_bfit()` call.

The IWLS updating functions find optimum smoothing variances according to an information criterion using a stepwise approach, i.e., in each iteration and for each model term update the updating functions try to find a better smoothing variance to control the trade-off between over-smoothing and nonlinear functional estimation. The search interval is centered around the current state of the smoothing variances, hence, in each iteration only a slight improvement is achieved. This algorithm is based on Belitz~and~Lang~(2008) and can also be viewed as a boosting approach for optimization.

## Value

For function `opt_bfit()` a list containing the following objects:

|                            |                                                                                           |
|----------------------------|-------------------------------------------------------------------------------------------|
| <code>fitted.values</code> | A named list of the fitted values of the modeled parameters of the selected distribution. |
| <code>parameters</code>    | The estimated set regression coefficients and smoothing variances.                        |
| <code>edf</code>           | The equivalent degrees of freedom used to fit the model.                                  |
| <code>logLik</code>        | The value of the log-likelihood.                                                          |
| <code>logPost</code>       | The value of the log-posterior.                                                           |
| <code>IC</code>            | The value of the information criterion.                                                   |
| <code>converged</code>     | Logical, indicating convergence of the backfitting algorithm.                             |

For updating functions a list providing the current state

|               |                                                                                                                                                                                                                                                                                                                     |
|---------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| fitted.values | The resulting fitted values after updating.                                                                                                                                                                                                                                                                         |
| parameters    | The resulting named numeric vector of updated model term parameters. Coefficients should be named with "b1", ..., "bk", where k is the total number of coefficients. Smoothing variances should be named with "tau21", ..., "tau2m", where m is the total number of smoothing variances assigned to the model term. |
| edf           | The equivalent degrees of freedom used to produce the fitted values.                                                                                                                                                                                                                                                |
| hessian       | Optional, the coefficient Hessian information                                                                                                                                                                                                                                                                       |
| log.prior     | Optional, the value of the log-prior of the model term.                                                                                                                                                                                                                                                             |

## References

- Belitz C, Lang S (2008). Simultaneous Selection of Variables and Smoothing Parameters in Structured Additive Regression Models. *Computational Statistics & Data Analysis*, **53**, pp 61-81.
- Umlauf N, Klein N, Zeileis A (2016). Bayesian Additive Models for Location Scale and Shape (and Beyond). *(to appear)*
- Rigby, R. A. and Stasinopoulos D. M. (2005). Generalized additive models for location, scale and shape, (with discussion), *Appl. Statist.*, **54**, part 3, pp 507-554.

## See Also

[bamlss](#), [bamlss.frame](#), [bamlss.engine.setup](#), [set.starting.values](#), [s2](#)

## Examples

```
## Not run: ## Simulated data example illustrating
## how to call the optimizer function.
## This is done internally within
## the setup of function bamlss().
d <- GAMart(n = 200)
f <- num ~ s(x1) + s(x2) + s(x3)
bf <- bamlss.frame(f, data = d, family = "gaussian")
opt <- with(bf, opt_bfit(x, y, family))
print(str(opt))

## Same with bamlss().
b <- bamlss(f, data = d, family = "gaussian", sampler = FALSE)
plot(b)
summary(b)

## Use of different updating function.
b <- bamlss(f, data = d, family = "gaussian",
  sampler = FALSE, update = bfit_lm)
plot(b)

## Use mgcv gam() function for updating.
b <- bamlss(f, data = d, family = "gaussian",
  sampler = FALSE, mgcv = TRUE)
plot(b)
```

```

## Special smooth constructor including updating/sampler
## function for nonlinear Gompertz curves.
## Note: element special.npar is needed here since this
##       function has 3 parameters but the design matrix only
##       one column!
smooth.construct.gc.smooth.spec <- function(object, data, knots)
{
  object$X <- matrix(as.numeric(data[[object$term]]), ncol = 1)
  center <- if(!is.null(object$xt$center)) {
    object$xt$center
  } else TRUE
  object$by.done <- TRUE
  if(object$by != "NA")
    stop("by variables not supported!")
  object$fit.fun <- function(X, b, ...) {
    f <- b[1] * exp(-b[2] * exp(-b[3] * drop(X)))
    if(center)
      f <- f - mean(f)
    f
  }
  object$update <- bfit_optim
  object$propose <- GMCMC_slice
  object$prior <- function(b) { sum(dnorm(b, sd = 1000, log = TRUE)) }
  object$fixed <- TRUE
  object$state$parameters <- c("b1" = 0, "b2" = 0.5, "b3" = 0.1)
  object$state$fitted.values <- rep(0, length(object$X))
  object$state$edf <- 3
  object$special.npar <- 3 ## Important!
  class(object) <- c("gc.smooth", "no.mgcv", "special")
  object
}

## Work around for the "prediction matrix" of a growth curve.
Predict.matrix.gc.smooth <- function(object, data, knots)
{
  X <- matrix(as.numeric(data[[object$term]]), ncol = 1)
  X
}

## Heteroscedastic growth curve data example.
set.seed(111)

d <- data.frame("time" = 1:30)
d$y <- 2 + 1 / (1 + exp(0.5 * (15 - d$time))) +
  rnorm(30, sd = exp(-3 + 2 * cos(d$time/30 * 6 - 3)))

## Special model terms must be called with s2()!
f <- list(
  y ~ s2(time, bs = "gc"),
  sigma ~ s(time)
)

## Fit model with special model term.

```



```

b <- bamlss(f, data = d,
  optimizer = opt_bfit, sampler = sam_GMCMC)

## Plot the fitted curves.
plot(b)

## Predict with special model term.
nd <- data.frame("time" = seq(1, 30, length = 100))
p <- predict(b, newdata = nd, model = "mu", FUN = c95)
plot(d, ylim = range(c(d$y, p)))
matplot(nd$time, p, type = "l",
  lty = c(2, 1, 2), col = "black", add = TRUE)

## End(Not run)

```

---

opt\_boost

*Boosting BAMLSS*


---

## Description

Optimizer functions for gradient and likelihood boosting with [bamlss](#). In each boosting iteration the function selects the model term with the largest contribution to the log-likelihood, AIC or BIC.

## Usage

```

## Gradient boosting optimizer.
opt_boost(x, y, family, weights = NULL,
  offset = NULL, nu = 0.1, nu.adapt = TRUE, df = 4, maxit = 400,
  mstop = NULL, maxq = NULL, qsel.splitfactor = FALSE,
  verbose = TRUE, digits = 4, flush = TRUE,
  eps = .Machine$double.eps^0.25,
  nback = NULL, plot = TRUE, initialize = TRUE,
  stop.criterion = NULL, select.type = 1,
  force.stop = TRUE, hatmatrix = !is.null(stop.criterion),
  reverse.edf = FALSE, approx.edf = FALSE,
  always = FALSE, ...)

boost(x, y, family, weights = NULL,
  offset = NULL, nu = 0.1, nu.adapt = TRUE, df = 4, maxit = 400,
  mstop = NULL, maxq = NULL, qsel.splitfactor = FALSE,
  verbose = TRUE, digits = 4, flush = TRUE,
  eps = .Machine$double.eps^0.25,
  nback = NULL, plot = TRUE, initialize = TRUE,
  stop.criterion = NULL, select.type = 1,
  force.stop = TRUE, hatmatrix = !is.null(stop.criterion),
  reverse.edf = FALSE, approx.edf = FALSE,
  always = FALSE, ...)

```

```

## Modified likelihood based boosting.
opt_boostm(x, y, family, offset = NULL,
  nu = 0.1, df = 3, maxit = 400, mstop = NULL,
  verbose = TRUE, digits = 4, flush = TRUE,
  eps = .Machine$double.eps^0.25, plot = TRUE,
  initialize = TRUE, stop.criterion = "BIC",
  force.stop = !is.null(stop.criterion),
  do.optim = TRUE, always = FALSE, ...)

boostm(x, y, family, offset = NULL,
  nu = 0.1, df = 3, maxit = 400, mstop = NULL,
  verbose = TRUE, digits = 4, flush = TRUE,
  eps = .Machine$double.eps^0.25, plot = TRUE,
  initialize = TRUE, stop.criterion = "BIC",
  force.stop = !is.null(stop.criterion),
  do.optim = TRUE, always = FALSE, ...)

## Boosting summary extractor.
boost_summary(object, ...)

## Plot all boosting paths.
boost_plot(x, which = c("loglik", "loglik.contrib", "parameters",
  "aic", "bic", "user"), intercept = TRUE, spar = TRUE, mstop = NULL,
  name = NULL, drop = NULL, labels = NULL, color = NULL, ...)

## Boosting summary printing and plotting.
## S3 method for class 'boost_summary'
print(x, summary = TRUE, plot = TRUE,
  which = c("loglik", "loglik.contrib"), intercept = TRUE,
  spar = TRUE, ...)
## S3 method for class 'boost_summary'
plot(x, ...)

## Model frame for out-of-sample selection.
boost_frame(formula, train, test, family = "gaussian", ...)

```

## Arguments

|         |                                                                                                                                                                                                                                                                                                                         |
|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| x       | For function <code>opt_boost()</code> the x list, as returned from function <code>bamlss.frame</code> , holding all model matrices and other information that is used for fitting the model. For the plotting function the corresponding <code>bamlss</code> object fitted with the <code>opt_boost()</code> optimizer. |
| y       | The model response, as returned from function <code>bamlss.frame</code> .                                                                                                                                                                                                                                               |
| family  | A <code>bamlss</code> family object, see <code>family.bamlss</code> .                                                                                                                                                                                                                                                   |
| weights | Prior weights on the data, as returned from function <code>bamlss.frame</code> .                                                                                                                                                                                                                                        |
| offset  | Can be used to supply model offsets for use in fitting, returned from function <code>bamlss.frame</code> .                                                                                                                                                                                                              |

|                  |                                                                                                                                                                                                                                                                                                                                                 |
|------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| nu               | Numeric, between [0, 1], controls the step size, i.e., the amount that should be added to model term parameters.                                                                                                                                                                                                                                |
| nu.adapt         | Logical. If set to TRUE (default) step size nu is divided by 2, if current boosting iteration did not improve the loglikelihood.                                                                                                                                                                                                                |
| df               | Integer, defines the initial degrees of freedom that should be assigned to each smooth model term. May also be a named vector, the names must match the model term labels, e.g., as provided in <a href="#">summary.bamlss</a> .                                                                                                                |
| maxit            | Integer, the maximum number of boosting iterations.                                                                                                                                                                                                                                                                                             |
| mstop            | For convenience, overwrites maxit.                                                                                                                                                                                                                                                                                                              |
| maxq             | Integer, defines the maximum number of selected base-learners. The algorithm stops if this numer is exceeded.                                                                                                                                                                                                                                   |
| qsel.splitfactor | Logical, if set to TRUE dummy variables of categorical predictors are counted individually.                                                                                                                                                                                                                                                     |
| name             | Character, the name of the coefficient (group) that should be plotted. Note that the string provided in name will be removed from the labels on the 4th axis.                                                                                                                                                                                   |
| drop             | Character, the name of the coefficient (group) that should not be plotted.                                                                                                                                                                                                                                                                      |
| labels           | A character string of labels that should be used on the 4 axis.                                                                                                                                                                                                                                                                                 |
| color            | Colors or color function that creates colors for the (group) paths.                                                                                                                                                                                                                                                                             |
| verbose          | Print information during runtime of the algorithm.                                                                                                                                                                                                                                                                                              |
| digits           | Set the digits for printing when verbose = TRUE.                                                                                                                                                                                                                                                                                                |
| flush            | use <a href="#">flush.console</a> for displaying the current output in the console.                                                                                                                                                                                                                                                             |
| eps              | The tolerance used as stopping mechanism, see argument nback.                                                                                                                                                                                                                                                                                   |
| nback            | Integer. If nback is not NULL, then the algorithm stops if the the change in the log-likelihood of the last nback iterations is smaller or equal to eps. If maxit = NULL the maximum number of iterations is set to 10000.                                                                                                                      |
| plot             | Should the boosting summary be printed and plotted?                                                                                                                                                                                                                                                                                             |
| initialize       | Logical, should intercepts be initialized?                                                                                                                                                                                                                                                                                                      |
| stop.criterion   | Character, selects the information criterion that should be used to determine the optimum number of boosting iterations. Either "AIC" or "BIC" is possible. Note that this feature requires to compute hat-matrices for each distributional parameter, therefore, the routine may be slow and computer storage intensive.                       |
| select.type      | Should model terms be selected by the log-likelihood contribution, select.type = 1, or by the corresponding stop.criterion, select.type = 2.                                                                                                                                                                                                    |
| force.stop       | Logical, should the algorithm stop if the information criterion increases?                                                                                                                                                                                                                                                                      |
| do.optim         | Logical. Should smoothing parameters be optimized in each boosting iteration?                                                                                                                                                                                                                                                                   |
| hatmatrix        | Logical, if set to TRUE the hat-matrices for each distributional parameter will be computed. The hat-matrices are used to determine the effective (equivalent) degrees of freedom in each boosting iteration, i.e., it is possible to compute information criteria like the AIC or BIC for selecting the optimum number of boosting iterations. |

|             |                                                                                                                                                                                                                                                                                                |
|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| reverse.edf | Logical. Instead of computing degrees of freedom with hat-matrices, the actual smoothing parameters are reverse engineered to compute the corresponding actual smoother matrix. Note that this option is still experimental.                                                                   |
| approx.edf  | Logical. Another experimental and fast approximation of the degrees of freedom.                                                                                                                                                                                                                |
| always      | Logical or character. Should the intercepts forced to be updated in each boosting iteration? If always = TRUE each intercept of each distributional parameter is updated, if always = "best" only the intercept corresponding to the distributional of the best fitting model term is updated. |
| object      | A <a href="#">bamlss</a> object that was fitted using <code>opt_boost()</code> .                                                                                                                                                                                                               |
| summary     | Should the summary be printed?                                                                                                                                                                                                                                                                 |
| which       | Which of the three provided plots should be created?                                                                                                                                                                                                                                           |
| intercept   | Should the coefficient paths of intercepts be dropped in the plot?                                                                                                                                                                                                                             |
| spar        | Should graphical parameters be set with <code>par</code> ?                                                                                                                                                                                                                                     |
| formula     | See <a href="#">bamlss.frame</a> .                                                                                                                                                                                                                                                             |
| train, test | Data frames used for training and testing the model..                                                                                                                                                                                                                                          |
| ...         | For function <code>opt_boost()</code> , arguments passed to <a href="#">bamlss.engine.setup</a> . for function <code>boost_summary()</code> arguments passed to function <code>print.boost_summary()</code> .                                                                                  |

### Value

For function `boost_summary()` a list containing information on selection frequencies etc. For function `opt_boost()` and `opt_boostm()` a list containing the following objects:

|               |                                                                                                                                |
|---------------|--------------------------------------------------------------------------------------------------------------------------------|
| fitted.values | A named list of the fitted values based on the last boosting iteration of the modeled parameters of the selected distribution. |
| parameters    | A matrix, each row corresponds to the parameter values of one boosting iteration.                                              |
| boost_summary | The boosting summary which can be printed and plotted.                                                                         |

### WARNINGS

The function does not take care of variable scaling for the linear parts! This must be done by the user, e.g., one option is to use argument `scale.d` in function [bamlss.frame](#), which uses `scale`.

Function `opt_boost()` does not select the optimum stopping iteration! The modified likelihood based algorithm implemented in function `opt_boostm()` is still experimental!

### See Also

[bamlss.frame](#), [bamlss](#)

**Examples**

```

## Not run: ## Simulate data.
set.seed(123)
d <- GAMart()

## Estimate model.
f <- num ~ x1 + x2 + x3 + lon + lat +
  s(x1) + s(x2) + s(x3) + s(lon) + s(lat) + te(lon,lat)

b <- bamlss(f, data = d, optimizer = opt_boost,
  sampler = FALSE, scale.d = TRUE, nu = 0.01,
  maxit = 1000, plot = FALSE)

## Plot estimated effects.
plot(b)

## Print and plot the boosting summary.
boost_summary(b, plot = FALSE)
boost_plot(b, which = 1)
boost_plot(b, which = 2)
boost_plot(b, which = 3, name = "mu.s.te(lon,lat).")

## Extract estimated parameters for certain
## boosting iterations.
parameters(b, mstop = 1)
parameters(b, mstop = 100)

## Also works with predict().
head(do.call("cbind", predict(b, mstop = 1)))
head(do.call("cbind", predict(b, mstop = 100)))

## Another example using the modified likelihood
## boosting algorithm.
f <- list(
  num ~ x1 + x2 + x3 + lon + lat +
    s(x1) + s(x2) + s(x3) + s(lon) + s(lat) + te(lon,lat),
  sigma ~ x1 + x2 + x3 + lon + lat +
    s(x1) + s(x2) + s(x3) + s(lon) + s(lat) + te(lon,lat)
)

b <- bamlss(f, data = d, optimizer = opt_boostm,
  sampler = FALSE, scale.d = TRUE, nu = 0.05,
  maxit = 400, stop.criterion = "AIC", force.stop = FALSE)

## Plot estimated effects.
plot(b)

## Plot AIC and log-lik contributions.
boost_plot(b, "AIC")
boost_plot(b, "loglik.contrib")

## Out-of-sample selection of model terms.

```

```

set.seed(123)
d <- GAMart(n = 5000)

## Split data into training and testing
i <- sample(1:2, size = nrow(d), replace = TRUE)
dtest <- subset(d, i == 1)
dtrain <- subset(d, i == 2)

## Model formula
f <- list(
  num ~ s(x1) + s(x2) + s(x3),
  sigma ~ s(x1) + s(x2) + s(x3)
)

## Create model frame for out-of-sample selection.
sm <- boost_frame(f, train = dtrain, test = dtest, family = "gaussian")

## Out-of-sample selection function.
sfun <- function(parameters) {
  sm$parameters <- parameters
  p <- predict(sm, type = "parameter")
  -1 * sum(sm$family$d(dtest$num, p, log = TRUE))
}

## Start boosting with out-of-sample negative
## log-likelihood selection of model terms.
b <- bamlss(f, data = dtrain, sampler = FALSE, optimizer = opt_boost,
  selectfun = sfun, always = "best")

## Plot curve of negative out-of-sample log-likelihood.
boost_plot(b, which = "user")

## End(Not run)

```

---

opt\_Cox

*Cox Model Posterior Mode Estimation*


---

## Description

This function computes posterior mode estimates of the parameters of a flexible Cox model with structured additive predictors using a Newton-Raphson algorithm. Integrals are solved numerically. Moreover, optimum smoothing variances are computed using a stepwise optimization, see also the details section of function [bfit](#).

## Usage

```

opt_Cox(x, y, start, weights, offset,
  criterion = c("AICc", "BIC", "AIC"),
  nu = 0.1, update.nu = TRUE,
  eps = .Machine$double.eps^0.25, maxit = 400,

```

```

    verbose = TRUE, digits = 4, ...)

cox_mode(x, y, start, weights, offset,
  criterion = c("AICc", "BIC", "AIC"),
  nu = 0.1, update.nu = TRUE,
  eps = .Machine$double.eps^0.25, maxit = 400,
  verbose = TRUE, digits = 4, ...)

```

### Arguments

|           |                                                                                                                                                                                                                |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| x         | The x list, as returned from function <code>bamlss.frame</code> and transformed by function <code>surv_transform</code> , holding all model matrices and other information that is used for fitting the model. |
| y         | The model response, as returned from function <code>bamlss.frame</code> .                                                                                                                                      |
| start     | A named numeric vector containing possible starting values, the names are based on function <code>parameters</code> .                                                                                          |
| weights   | Prior weights on the data, as returned from function <code>bamlss.frame</code> .                                                                                                                               |
| offset    | Can be used to supply model offsets for use in fitting, returned from function <code>bamlss.frame</code> .                                                                                                     |
| criterion | Set the information criterion that should be used, e.g., for smoothing variance selection. Options are the corrected AIC "AICc", the "BIC" and "AIC".                                                          |
| nu        | Calibrates the step length of parameter updates of one Newton-Raphson update.                                                                                                                                  |
| update.nu | Should the updating step length be optimized in each iteration of the backfitting algorithm.                                                                                                                   |
| eps       | The relative convergence tolerance of the backfitting algorithm.                                                                                                                                               |
| maxit     | The maximum number of iterations for the backfitting algorithm                                                                                                                                                 |
| verbose   | Print information during runtime of the algorithm.                                                                                                                                                             |
| digits    | Set the digits for printing when <code>verbose = TRUE</code> .                                                                                                                                                 |
| ...       | Currently not used.                                                                                                                                                                                            |

### Value

A list containing the following objects:

|               |                                                                                           |
|---------------|-------------------------------------------------------------------------------------------|
| fitted.values | A named list of the fitted values of the modeled parameters of the selected distribution. |
| parameters    | The estimated set regression coefficients and smoothing variances.                        |
| edf           | The equivalent degrees of freedom used to fit the model.                                  |
| logLik        | The value of the log-likelihood.                                                          |
| logPost       | The value of the log-posterior.                                                           |
| hessian       | The Hessian matrix evaluated at the posterior mode.                                       |
| converged     | Logical, indicating convergence of the backfitting algorithm.                             |
| time          | The runtime of the algorithm.                                                             |

**References**

Umlauf N, Klein N, Zeileis A (2016). Bayesian Additive Models for Location Scale and Shape (and Beyond). *(to appear)*

**See Also**

[sam\\_Cox](#), [cox\\_bamlss](#), [surv\\_transform](#), [simSurv](#), [bamlss](#)

**Examples**

```
## Please see the examples of function sam_Cox()!
```

---

opt\_isgd

*Implicit Stochastic Gradient Descent Optimizer*

---

**Description**

This optimizer performs an implicit stochastic gradient descent algorithm. It is mainly used within a [bamlss](#) call.

**Usage**

```
opt_isgd(x, y, family, weights = NULL, offset = NULL,
         gammaFun = function(i) 1/(1 + i), shuffle = TRUE,
         CFun = function(beta) diag(length(beta)),
         start = NULL, i.state = 0)
```

**Arguments**

|          |                                                                                                                                                                                          |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| x        | For function <code>boost()</code> the x list, as returned from function <code>bamlss.frame</code> , holding all model matrices and other information that is used for fitting the model. |
| y        | The model response, as returned from function <code>bamlss.frame</code> .                                                                                                                |
| family   | A <b>bamlss</b> family object, see <code>family.bamlss</code> .                                                                                                                          |
| weights  | Prior weights on the data, as returned from function <code>bamlss.frame</code> .                                                                                                         |
| offset   | Can be used to supply model offsets for use in fitting, returned from function <code>bamlss.frame</code> .                                                                               |
| gammaFun | Function specifying the step length.                                                                                                                                                     |
| shuffle  | Should the data be shuffled?                                                                                                                                                             |
| CFun     | Hessian approximating function.                                                                                                                                                          |
| start    | Vector of starting values.                                                                                                                                                               |
| i.state  | Added to <code>gammaFUN()</code> .                                                                                                                                                       |

**Details**

tpf



**Value**

For function `opt_isgd()` a list containing the following objects:

|                            |                                                                                                                       |
|----------------------------|-----------------------------------------------------------------------------------------------------------------------|
| <code>fitted.values</code> | A named list of the fitted values based on the last iteration of the modeled parameters of the selected distribution. |
| <code>parameters</code>    | A matrix, each row corresponds to the parameter values of one iteration.                                              |
| <code>sgd.summary</code>   | The summary of the stochastic gradient descent algorithm which can be printed and plotted.                            |

**Warning**

CAUTION: Arguments `weights` and `offset` are not implemented yet!

**Note**

Motivated by the lecture 'Regression modelling with large data sets' given by Ioannis Kosmidis in Innsbruck, January 2017.

**Author(s)**

Thorsten Simon

**References**

Toulis, P and Airoidi, EM (2015): Scalable estimation strategies based on stochastic approximations: Classical results and new insights. *Statistics and Computing*, 25, no. 4, 781–795. doi: 10.1007/s11222-015-9560-y

**See Also**

[bamlss.frame](#), [bamlss](#)

**Examples**

```
## Not run:
set.seed(111)
d <- GAMart(n = 10000)
f <- num ~ s(x1) + s(x2) + s(x3) + te(lon, lat)
b <- bamlss(f, data = d, optimizer = opt_isgd, sampler = FALSE)
plot(b, ask = F)

## loop over observations a 2nd time
b <- bamlss(f, data = d, optimizer = opt_isgd, sampler = FALSE, start = parameters(b),
           i.state = b$model.stats$optimizer$sgd.summary$i.state)
plot(b, ask = F)

## try different gammaFuns, e.g.,
# gammaFun <- function(i) .3/sqrt((1+i)) + 0.001

## testing some families
```

```
f2 <- bin ~ s(x1) + s(x2) + s(x3) + te(lon, lat)
b2 <- bamlss(f2, data = d, optimizer = opt_isgd, sampler = FALSE, family = "binomial")

f3 <- cens ~ s(x1) + s(x2) + s(x3) + te(lon, lat)
b3 <- bamlss(f3, data = d, optimizer = opt_isgd, sampler = FALSE, family = "cnorm")

## End(Not run)
```

---

parameters

*Extract or Initialize Parameters for BAMLSS*


---

### Description

The function either sets up a list of all parameters of a `bamlss.frame`, which can be used for setting up models, or extracts the estimated parameters of a `bamlss` object.

### Usage

```
parameters(x, model = NULL, start = NULL,
  fill = c(0, 1e-04), list = FALSE,
  simple.list = FALSE, extract = FALSE,
  ...)
```

### Arguments

|                          |                                                                                                                                                                                                                |
|--------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>x</code>           | A <code>bamlss.frame</code> or <code>bamlss</code> object.                                                                                                                                                     |
| <code>model</code>       | The model name for which parameters should be initialized or extracted.                                                                                                                                        |
| <code>start</code>       | A named numeric vector which should be used when creating the parameter list. See also function <code>link{set.starting.values}</code>                                                                         |
| <code>fill</code>        | Numeric, when setting up a parameter list, the values the should be used for regression coefficients (first element of <code>fill</code> ) and for smoothing variances (second element of <code>fill</code> ). |
| <code>list</code>        | Should the function return a list of all parameters?                                                                                                                                                           |
| <code>simple.list</code> | Should the names of parameter vectors be dropped?                                                                                                                                                              |
| <code>extract</code>     | Should parameters of a <code>bamlss.frame</code> be extracted or initialized?                                                                                                                                  |
| <code>...</code>         | Currently not used.                                                                                                                                                                                            |

### Details

Parameters for BAMLSS are used for optimizer functions in function `bamlss`. The function is useful for initializing all parameters given a `bamlss.frame` (which is done internally in function `bamlss`), but also for extracting all estimated parameters of some optimizer.

The naming convention of the parameter list is used by a couple of functions in this package. For each parameter of the modeled distribution, e.g., `gaussian_bamlss` has parameters "mu" and "sigma", a list element is created. These elements the contain the list of all model term parameters.

Parametric model terms are indicated with "p" and smooth model terms with "s". If the design matrix of a model term in the x list of a `bamlss.frame` does not contain any column names, then the parameters are named with a leading "b", otherwise the column names of the design matrix are used. Smoothing variances parameter vectors are named with a leading "tau2".

The naming convention is useful when setting up new model fitting engines for `bamlss` and is used, e.g., by `bfit` and `GMCMC`, which are based on parameter state list objects as provided by function `bamlss.engine.setup`.

### Value

A named list of all parameters of a `bamlss.frame` or `bamlss` object.

### See Also

`bamlss.frame`, `bamlss`, `opt_bfit`, `sam_GMCMC`, `get.par`, `set.par`

### Examples

```
## Create a "bamlss.frame"
set.seed(123)
d <- GAMart()
bf <- bamlss.frame(num ~ s(x1) + te(lon,lat), data = d)

## Create list of all parameters from "bamlss.frame".
p <- parameters(bf, list = TRUE)
str(p)

## Not run: ## Estimate model.
f <- list(num ~ s(x1) + te(lon,lat), sigma ~ s(x1))
b <- bamlss(f, data = d, sampler = FALSE)

## Extract estimated parameters.
parameters(b)
parameters(b, list = TRUE)

## End(Not run)
```

---

pathplot

*Plot Coefficients Paths*

---

### Description

This is a simple wrapper function to plot coefficients paths obtained from the boosting optimizer function `boost` and the LASSO optimizer `lasso`.

### Usage

```
pathplot(object, ...)
```

**Arguments**

object            An object of class "bamlss".  
 ...                Arguments passed to [boost\\_plot](#) or [lasso\\_plot](#).

**See Also**

[boost\\_plot](#), [lasso\\_plot](#)

---

plot.bamlss

*Plotting BAMLSS*

---

**Description**

Plotting methods for objects of class "bamlss" and "bamlss.results", which can be used for producing effect plots of model terms, trace plots of samples or residual plots. Note that effect plots of model terms with more than two covariates are not supported, for this purpose use function [predict.bamlss](#).

**Usage**

```
## S3 method for class 'bamlss'
plot(x, model = NULL, term = NULL,
     which = "effects", parameters = FALSE,
     ask = dev.interactive(), spar = TRUE, ...)

## S3 method for class 'bamlss.results'
plot(x, model = NULL, term = NULL,
     ask = dev.interactive(), scale = 1, spar = TRUE, ...)
```

**Arguments**

x                    An object of class "bamlss" or "bamlss.results".  
 model                Character or integer. For which model should the plots be created?  
 term                 Character or integer. For which model term should a plot be created?  
 which                Character or integer, selects the type of plot: "effects" produces effect plots of smooth model terms, "samples" shows trace plots of samples, "hist-resid" shows a histogram of residuals (see also [residuals.bamlss](#) for the different available types), "qq-resid" shows a quantile-quantile plot of residuals, "scatter-resid" shows a scatter plot of residuals with fitted values for the distribution mean (if available in the family object), "max-acf" shows an [acf](#) plot of the maximum autocorrelation of all parameter samples.  
 parameters          For trace plots of parameters, should corresponding parameter values as returned from an optimizer function (e.g., [opt\\_bfit](#)) be added as horizontal lines?  
 ask                  For multiple plots, the user is asked to show the next plot.

|       |                                                                                                                                                                                                    |
|-------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| scale | If set to 1, effect plots all have the same scale on the y-axis. If set to 0 each effect plot has its own scale for the y-axis.                                                                    |
| spar  | Should graphical parameters be set?                                                                                                                                                                |
| ...   | Arguments to be passed to <a href="#">plot2d</a> , <a href="#">plot3d</a> , <a href="#">sliceplot</a> , <a href="#">plotblock</a> , <a href="#">plotmap</a> and <a href="#">residuals.bamlss</a> . |

**See Also**

[bamlss](#), [results.bamlss.default](#), [residuals.bamlss](#).

**Examples**

```
## Not run: ## Generate some data.
d <- GAMart()

## Model formula.
f <- list(
  num ~ s(x1) + s(x2) + s(x3) + te(lon,lat),
  sigma ~ s(x2) + te(lon,lat)
)

## Estimate model.
b <- bamlss(f, data = d)

## Effect plots
plot(b, ask = FALSE)
plot(b, model = "mu")
plot(b, model = "sigma", term = "te(lon,lat)")

## Trace plots.
plot(b, which = "samples")

## Residual plots.
plot(b, which = 3:4)

## End(Not run)
```

---

plot2d

*Plot 2D Effects*


---

**Description**

Function to plot simple 2D graphics for univariate effects/functions.

**Usage**

```
plot2d(x, residuals = FALSE, rug = FALSE, jitter = TRUE,
  col.residuals = NULL, col.lines = NULL, col.polygons = NULL,
  col.rug = NULL, c.select = NULL, fill.select = NULL,
```

```
data = NULL, sep = "", month = NULL, year = NULL,
step = 12, shift = NULL, trans = NULL,
scheme = 2, s2.col = NULL, grid = 50, ...)
```

### Arguments

|                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|-------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| x                 | A matrix or data frame, containing the covariate for which the effect should be plotted in the first column and at least a second column containing the effect. Another possibility is to specify the plot via a formula, e.g. $y \sim x$ , see the examples. x may also be a character file path to the data to be used for plotting.                                                                                                                                                                                                                                                                                |
| residuals         | If set to TRUE, residuals may also be plotted if available. Residuals must be supplied as an <code>attribute</code> named "residuals", which is a matrix or data frame where the first column is the covariate and the second column the residuals.                                                                                                                                                                                                                                                                                                                                                                   |
| rug               | Add a <code>rug</code> to the plot.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| jitter            | If set to TRUE a <code>jittered rug</code> plot is added.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| col.residuals     | The color of the partial residuals.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| col.lines         | The color of the lines.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| col.polygons      | Specify the background color of polygons, if x has at least 3 columns, i.e. column 2 and 3 can form one polygon.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| col.rug           | Specify the color of the rug representation.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| c.select          | Integer vector of maximum length of columns of x, selects the columns of the resulting data matrix that should be used for plotting. E.g. if x has 5 columns, then <code>c.select = c(1, 2, 5)</code> will select column 1, 2 and 5 for plotting. Note that first element of <code>c.select</code> should always be the column that holds the variable for the x-axis.                                                                                                                                                                                                                                                |
| fill.select       | Integer vector, select pairwise the columns of the resulting data matrix that should form one polygon with a certain background color specified in argument <code>col</code> . E.g. x has three columns, or is specified with formula $f1 + f2 \sim x$ , then setting <code>fill.select = c(0, 1, 1)</code> will draw a polygon with <code>f1</code> and <code>f2</code> as boundaries. If x has five columns or the formula is e.g. $f1 + f2 + f3 + f4 \sim x$ , then setting <code>fill.select = c(0, 1, 1, 2, 2)</code> , the pairs <code>f1, f2</code> and <code>f3, f4</code> are selected to form two polygons. |
| data              | If x is a formula, a <code>data.frame</code> or <code>list</code> . By default the variables are taken from <code>environment(x)</code> : typically the environment from which <code>plot2d</code> is called. Note that data may also be a character file path to the data.                                                                                                                                                                                                                                                                                                                                           |
| sep               | The field separator character when x or data is a character, see function <code>read.table</code> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| month, year, step | Provide specific annotation for plotting estimation results for temporal variables. <code>month</code> and <code>year</code> define the minimum time point whereas <code>step</code> specifies the type of temporal data with <code>step = 4</code> , <code>step = 2</code> and <code>step = 1</code> corresponding to quarterly, half yearly and yearly data.                                                                                                                                                                                                                                                        |
| shift             | Numeric constant to be added to the smooth before plotting.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| trans             | Function to be applied to the smooth before plotting, e.g., to transform the plot to the response scale.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |

|        |                                                                           |
|--------|---------------------------------------------------------------------------|
| scheme | Sets the plotting scheme for polygons, possible values are 1 and 2.       |
| s2.col | The color for the second plotting scheme.                                 |
| grid   | Integer, specifies the number of polygons for the second plotting scheme. |
| ...    | Other graphical parameters, please see the details.                       |

### Details

For 2D plots the following graphical parameters may be specified additionally:

- `cex`: Specify the size of partial residuals,
- `lty`: The line type for each column that is plotted, e.g. `lty = c(1, 2)`,
- `lwd`: The line width for each column that is plotted, e.g. `lwd = c(1, 2)`,
- `poly.lty`: The line type to be used for the polygons,
- `poly.lwd`: The line width to be used for the polygons,
- `density angle, border`: See [polygon](#),
- ...: Other graphical parameters, see function [plot](#).

### See Also

[plot3d](#), [plotmap](#), [plotblock](#), [sliceplot](#).

### Examples

```
## Generate some data.
set.seed(111)
n <- 500
## Regressor.
d <- data.frame(x = runif(n, -3, 3))

## Response.
d$y <- with(d, 10 + sin(x) + rnorm(n, sd = 0.6))

## Not run: ## Estimate model.
b <- bamlss(y ~ s(x), data = d)
summary(b)

## Plot estimated effect.
plot(b)
plot(b, rug = FALSE)

## Extract fitted values.
f <- fitted(b, model = "mu", term = "s(x)")
f <- cbind(d["x"], f)

## Now use plot2d.
plot2d(f)
plot2d(f, fill.select = c(0, 1, 0, 1))
plot2d(f, fill.select = c(0, 1, 0, 1), lty = c(2, 1, 2))
plot2d(f, fill.select = c(0, 1, 0, 1), lty = c(2, 1, 2),
```

```

    scheme = 2)

## Variations.
plot2d(sin(x) ~ x, data = d)
d$f <- with(d, sin(d$x))
plot2d(f ~ x, data = d)
d$f1 <- with(d, f + 0.1)
d$f2 <- with(d, f - 0.1)
plot2d(f1 + f2 ~ x, data = d)
plot2d(f1 + f2 ~ x, data = d, fill.select = c(0, 1, 1), lty = 0)
plot2d(f1 + f2 ~ x, data = d, fill.select = c(0, 1, 1), lty = 0,
  density = 20, poly.lty = 1, poly.lwd = 2)
plot2d(f1 + f + f2 ~ x, data = d, fill.select = c(0, 1, 0, 1),
  lty = c(0, 1, 0), density = 20, poly.lty = 1, poly.lwd = 2)

## End(Not run)

```

---

plot3d

*Plot 3D Effects*


---

## Description

Function to plot 3D graphics or image and/or contour plots for bivariate effects/functions.

## Usage

```

plot3d(x, residuals = FALSE, col.surface = NULL,
  ncol = 99L, swap = FALSE, col.residuals = NULL, col.contour = NULL,
  c.select = NULL, grid = 30L, image = FALSE, contour = FALSE,
  legend = TRUE, cex.legend = 1, breaks = NULL, range = NULL,
  digits = 2L, d.persp = 1L, r.persp = sqrt(3), outscale = 0,
  data = NULL, sep = "", shift = NULL, trans = NULL,
  type = "mba", linear = FALSE, extrap = FALSE,
  k = 40, ...)

```

## Arguments

|             |                                                                                                                                                                                                                                                                                                                                                                                                 |
|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| x           | A matrix or data frame, containing the covariates for which the effect should be plotted in the first and second column and at least a third column containing the effect. Another possibility is to specify the plot via a formula, e.g. for simple plotting of bivariate surfaces $z \sim x + y$ , see the examples. x may also be a character file path to the data to be used for plotting. |
| residuals   | If set to TRUE, residuals may also be plotted if available. Residuals must be supplied as an <code>attribute</code> named "residuals", which is a matrix or data frame where the first two columns are covariates and the third column the residuals.                                                                                                                                           |
| col.surface | The color of the surface, may also be a function, e.g. <code>col.surface = heat.colors</code> .                                                                                                                                                                                                                                                                                                 |
| ncol        | the number of different colors that should be generated, if <code>col.surface</code> is a function.                                                                                                                                                                                                                                                                                             |



|               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|---------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| swap          | If set to TRUE colors will be represented in reverse order.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| col.residuals | The color of the partial residuals, or if <code>contour = TRUE</code> the color of the contour lines.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| col.contour   | The color of the contour lines.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| c.select      | Integer vector of maximum length of columns of <code>x</code> , selects the columns of the resulting data matrix that should be used for plotting. E.g. if <code>x</code> has 5 columns, then <code>c.select = c(1, 2, 5)</code> will select column 1, 2 and 5 for plotting. If <code>c.select = 95</code> or <code>c.select = 80</code> , function <code>plot3d</code> will search for the corresponding columns to plot a 95% or 80% confidence surfaces respectively. Note that if e.g. <code>c.select = c(1, 2)</code> , <code>plot3d</code> will use columns 1 + 2 and 2 + 2 for plotting. |
| grid          | The grid size of the surface(s).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| image         | If set to TRUE, an <code>image.plot</code> is drawn.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| contour       | If set to TRUE, a <code>contour</code> plot is drawn.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| legend        | If <code>image = TRUE</code> an additional legend may be added to the plot.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| cex.legend    | The expansion factor for the legend text, see <code>text</code> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| breaks        | A set of breakpoints for the colors: must give one more breakpoint than <code>ncol</code> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| range         | Specifies a certain range values should be plotted for.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| digits        | Specifies the legend decimal places.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| d.persp       | See argument <code>d</code> in function <code>persp</code> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| r.persp       | See argument <code>r</code> in function <code>persp</code> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| outscale      | Scales the outer ranges of <code>x</code> and <code>z</code> limits used for interpolation.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| data          | If <code>x</code> is a formula, a <code>data.frame</code> or <code>list</code> . By default the variables are taken from <code>environment(x)</code> : typically the environment from which <code>plot3d</code> is called. Note that <code>data</code> may also be a character file path to the data.                                                                                                                                                                                                                                                                                           |
| sep           | The field separator character when <code>x</code> or <code>data</code> is a character, see function <code>read.table</code> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| shift         | Numeric constant to be added to the smooth before plotting.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| trans         | Function to be applied to the smooth before plotting, e.g., to transform the plot to the response scale.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| type          | Character, which type of interpolation method should be used. The default is <code>type = "akima"</code> , see function <code>interp</code> . The two other options are <code>type = "mba"</code> , which calls function <code>mba.surf</code> of package <code>MBA</code> , or <code>type = "mgcv"</code> , which uses a spatial smoother withing package <code>mgcv</code> for interpolation. The last option is definitely the slowest, since a full regression model needs to be estimated.                                                                                                 |
| linear        | Logical, should linear interpolation be used withing function <code>interp</code> ?                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| extrap        | Logical, should interpolations be computed outside the observation area (i.e., extrapolated)?                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| k             | Integer, the number of basis functions to be used to compute the interpolated surface when <code>type = "mgcv"</code> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| ...           | Parameters passed to <code>colorlegend</code> if an image plot with legend is drawn, also other graphical parameters, please see the details.                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

## Details

For 3D plots the following graphical parameters may be specified additionally:

- `cex`: Specify the size of partial residuals,
- `col`: It is possible to specify the color for the surfaces if `se > 0`, then e.g. `col = c("green", "black", "red")`,
- `pch`: The plotting character of the partial residuals,
- ...: Other graphical parameters passed functions `persp`, `image.plot` and `contour`.

## Note

Function `plot3d` can use the **akima** package to construct smooth interpolated surfaces, therefore, package **akima** needs to be installed. The **akima** package has an ACM license that restricts applications to non-commercial usage, see

<https://www.acm.org/publications/policies/software-copyright-notice>

Function `plot3d` prints a note referring to the ACM license. This note can be suppressed by setting `options("use.akima" = TRUE)`

## See Also

[colorlegend](#), [plot2d](#), [plotmap](#), [plotblock](#), [sliceplot](#).

## Examples

```
## Generate some data.
set.seed(111)
n <- 500

## Regressors.
d <- data.frame(z = runif(n, -3, 3), w = runif(n, 0, 6))

## Response.
d$y <- with(d, 1.5 + cos(z) * sin(w) + rnorm(n, sd = 0.6))

## Not run: ## Estimate model.
b <- bamlss(y ~ s(z,w), data = d)
summary(b)

## Plot estimated effect.
plot(b, model = "mu", term = "s(z,w)")

## Extract fitted values.
f <- fitted(b, model = "mu", term = "s(z,w)", intercept = FALSE)
f <- cbind(d[, c("z", "w")], f)

## Now use plot3d().
plot3d(f)
plot3d(f, swap = TRUE)
plot3d(f, grid = 100, border = NA)
```

```

## Only works if columns are named with
## '2.5
plot3d(f, c.select = 95, border = c("red", NA, "green"),
      col.surface = c(1, NA, 1), resid = TRUE, cex.resid = 0.2)

## Now some image and contour.
# plot3d(f, image = TRUE, legend = FALSE)
# plot3d(f, image = TRUE, legend = TRUE)
# plot3d(f, image = TRUE, contour = TRUE)
# plot3d(f, image = TRUE, contour = TRUE, swap = TRUE)
# plot3d(f, image = TRUE, contour = TRUE, col.contour = "white")
# plot3d(f, contour = TRUE)
# plot3d(f, image = TRUE, contour = TRUE, c.select = 3)
# plot3d(f, image = TRUE, contour = TRUE, c.select = "Mean")
# plot3d(f, image = TRUE, contour = TRUE, c.select = "97.5")

## End(Not run)

## Variations.
d$f1 <- with(d, sin(z) * cos(w))
with(d, plot3d(cbind(z, w, f1)))

## Same with formula.
plot3d(sin(z) * cos(w) ~ z + w, zlab = "f(z,w)", data = d)
plot3d(sin(z) * cos(w) ~ z + w, zlab = "f(z,w)", data = d,
      ticktype = "detailed")

## Play with palettes.
plot3d(sin(z) * cos(w) ~ z + w, col.surface = heat.colors, data = d)
plot3d(sin(z) * cos(w) ~ z + w, col.surface = topo.colors, data = d)
plot3d(sin(z) * cos(w) ~ z + w, col.surface = cm.colors, data = d)
plot3d(sin(z) * cos(w) ~ z + w, col.surface = rainbow, data = d)
plot3d(sin(z) * cos(w) ~ z + w, col.surface = terrain.colors, data = d)

plot3d(sin(z) * cos(w) ~ z + w, col.surface = rainbow_hcl, data = d)
plot3d(sin(z) * cos(w) ~ z + w, col.surface = diverge_hcl, data = d)
plot3d(sin(z) * cos(w) ~ z + w, col.surface = sequential_hcl, data = d)

plot3d(sin(z) * cos(w) ~ z + w,
      col.surface = rainbow_hcl(n = 99, c = 300, l = 80, start = 0, end = 100),
      data = d)
# plot3d(sin(z) * cos(w) ~ z + w,
#       col.surface = rainbow_hcl(n = 99, c = 300, l = 80, start = 0, end = 100),
#       image = TRUE, grid = 200, data = d)

```

**Description**

Function to plot effects for model terms including factor, or group variables for random effects.

**Usage**

```
plotblock(x, residuals = FALSE, range = c(0.3, 0.3),
  col.residuals = "black", col.lines = "black", c.select = NULL,
  fill.select = NULL, col.polygons = NULL, data = NULL,
  shift = NULL, trans = NULL, labels = NULL, ...)
```

**Arguments**

|                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|----------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>x</code>             | Either a list of length of the unique factors, where each list element contains the estimated effects for one factor as a matrix, or one data matrix with first column as the group or factor variable. Also formulas are accepted, e.g. it is possible to specify the plot with $f \sim x$ or $f_1 + f_2 \sim x$ . By convention, the covariate for which effects should be plotted, is always in the first column in the resulting data matrix, that is used for plotting, i.e. in the second formula example, the data matrix is <code>cbind(x, f1, f2)</code> , also see argument <code>c.select</code> and <code>fill.select</code> .            |
| <code>residuals</code>     | If set to TRUE, residuals will be plotted if available. Residuals may be set as an attribute of <code>x</code> named "residuals", where the residuals must be a matrix with first column specifying the covariate, and second column the residuals that should be plotted.                                                                                                                                                                                                                                                                                                                                                                            |
| <code>range</code>         | Numeric vector, specifying the left and right bound of the block.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <code>col.residuals</code> | The color of the partial residuals.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <code>col.lines</code>     | Vector of maximum length of columns of <code>x</code> minus 1, specifying the color of the lines.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <code>c.select</code>      | Integer vector of maximum length of columns of <code>x</code> , selects the columns of the resulting data matrix that should be used for plotting. E.g. if <code>x</code> has 5 columns, then <code>c.select = c(1, 2, 5)</code> will select column 1, 2 and 5 for plotting. Note that first element of <code>c.select</code> should always be 1, since this is the column of the covariate the effect is plotted for.                                                                                                                                                                                                                                |
| <code>fill.select</code>   | Integer vector, select pairwise the columns of the resulting data matrix that should form one polygon with a certain background color specified in argument <code>col</code> . E.g. <code>x</code> has three columns, or is specified with formula $f_1 + f_2 \sim x$ , then setting <code>fill.select = c(0, 1, 1)</code> will draw a polygon with <code>f1</code> and <code>f2</code> as boundaries. If <code>x</code> has five columns or the formula is e.g. $f_1 + f_2 + f_3 + f_4 \sim x$ , then setting <code>fill.select = c(0, 1, 1, 2, 2)</code> , the pairs <code>f1, f2</code> and <code>f3, f4</code> are selected to form two polygons. |
| <code>col.polygons</code>  | Specify the background color for the upper and lower confidence bands, e.g. <code>col = c("green", "red")</code> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <code>data</code>          | If <code>x</code> is a formula, a data.frame or list. By default the variables are taken from <code>environment(x)</code> : typically the environment from which <code>plotblock</code> is called.                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <code>shift</code>         | Numeric constant to be added to the smooth before plotting.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <code>trans</code>         | Function to be applied to the smooth before plotting, e.g., to transform the plot to the response scale.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <code>labels</code>        | Character, labels for the factor levels.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <code>...</code>           | Graphical parameters, please see the details.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

## Details

Function `plotblock` draws for every factor or group the effect as a "block" in one graphic, i.e., similar to boxplots, estimated fitted effects, e.g., containing quantiles of MCMC samples, are drawn as one block, where the upper lines represent upper quantiles, the middle line the mean or median, and lower lines lower quantiles, also see the examples. The following graphical parameters may be supplied additionally:

- `cex`: Specify the size of partial residuals,
- `lty`: The line type for each column that is plotted, e.g. `lty = c(1, 2)`,
- `lwd`: The line width for each column that is plotted, e.g. `lwd = c(1, 2)`,
- `poly.lty`: The line type to be used for the polygons,
- `poly.lwd`: The line width to be used for the polygons,
- `density angle, border`: See [polygon](#),
- `...`: Other graphical parameters, see function [plot](#).

## See Also

[plot2d](#), [plot3d](#), [plotmap](#), [sliceplot](#).

## Examples

```
## Generate some data.
set.seed(111)
n <- 500

## Regressors.
d <- data.frame(fac = factor(rep(1:10, n/10)))

## Response.
d$y <- with(d, 1.5 + rnorm(10, sd = 0.6)[fac] +
  rnorm(n, sd = 0.6))

## Not run: ## Estimate model.
b <- bamlss(y ~ s(fac,bs="re"), data = d)
summary(b)

## Plot random effects.
plot(b)

## Extract fitted values.
f <- fitted(b, model = "mu", term = "fac")
f <- cbind(d["fac"], f)

## Now use plotblock.
plotblock(f)

## Variations.
plotblock(f, fill.select = c(0, 1, 0, 1), col.poly = "red")
plotblock(f, fill.select = c(0, 1, 0, 1), col.poly = "lightgray",
```

```

lty = c(2, 1, 2), lwd = c(2, 1, 2))

## End(Not run)

## More examples.
plotblock(y ~ fac, data = d, range = c(0.45, 0.45))

d <- data.frame(fac = factor(rep(1:10, n/10)))
d$y <- with(d, c(2.67, 5, 6, 3, 4, 2, 6, 7, 9, 7.5)[fac])
plotblock(y ~ fac, data = d)
plotblock(cbind(y - 0.1, y + 0.1) ~ fac, data = d)

```

---

plotmap

*Plot Maps*


---

### Description

The function takes a [list](#) polygons and draws the corresponding map. Different colors for each polygon can be used.

### Usage

```

plotmap(map, x = NA, id = NULL, select = NULL,
        legend = TRUE, names = FALSE, values = FALSE, ...)

```

### Arguments

|        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|--------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| map    | The map to be plotted, usually an object that inherits from <a href="#">SpatialPolygons</a> , but may also be a list of polygons, i.e., each list entry is a matrix with x- and y-coordinates.                                                                                                                                                                                                                                                                                                        |
| x      | A vector, data.frame or matrix. In the latter case x should have two columns, one column that is the region identifier and one that contains the values to be plotted. In case x is a data.frame, the function searches for "character" or "factor" columns for the region identifier. If x is a matrix, the second column of x is supposed to be the region identifier. If x = NA and map is an object of class "SpatialPolygonsDataFrame" only the polygons will be plotted without using the data. |
| id     | If argument x is a vector, argument id should contain the region identifier vector.                                                                                                                                                                                                                                                                                                                                                                                                                   |
| select | Select the column of the data in x which should be used for plotting, may be an integer or character with the corresponding column name.                                                                                                                                                                                                                                                                                                                                                              |
| legend | Should a color legend be added to the plot, see also function <a href="#">colorlegend</a> .                                                                                                                                                                                                                                                                                                                                                                                                           |
| names  | If set to TRUE the name for each polygon will also be plotted at the centroids of the corresponding polygons.                                                                                                                                                                                                                                                                                                                                                                                         |
| values | If set to TRUE the corresponding values for each polygon will also be plotted at the centroids of the polygons.                                                                                                                                                                                                                                                                                                                                                                                       |
| ...    | Arguments to be passed to <a href="#">colorlegend</a> and others, e.g. change the border of the polygons and density (mdensity for missing regions in id), see <a href="#">polygon</a> .                                                                                                                                                                                                                                                                                                              |

**See Also**

[plot2d](#), [plot3d](#), [sliceplot](#), [plotblock](#).

**Examples**

```
## Example from mgcv ?mrf.
## Load Columbus Ohio crime data (see ?columbus for details and credits).
data("columb", package = "mgcv")
data("columb.polys", package = "mgcv")

## Plot the map.
plotmap(columb.polys)

## Plot aggregated data.
a <- with(columb, aggregate(crime,
  by = list("district" = district), FUN = mean))

plotmap(columb.polys, x = a$x, id = a$district)
plotmap(columb.polys, x = a$x, id = a$district,
  pos = "topleft")
plotmap(columb.polys, x = a$x, id = a$district,
  pos = "topleft", side.legend = 2)
plotmap(columb.polys, x = a$x, id = a$district,
  pos = "topleft", side.legend = 2, side.ticks = 2)
plotmap(columb.polys, x = a$x, id = a$district,
  pos = "topleft", side.legend = 2, side.ticks = 2,
  col = heat_hcl, swap = TRUE)
plotmap(columb.polys, x = a$x, id = a$district,
  pos = "topleft", side.legend = 2, side.ticks = 2,
  col = heat_hcl, swap = TRUE, range = c(10, 50))
plotmap(columb.polys, x = a$x, id = a$district,
  pos = "topleft", side.legend = 2, side.ticks = 2,
  col = heat_hcl(5), swap = TRUE, range = c(10, 50),
  lrange = c(0, 60))
```

---

predict.bamlss

*BAMLSS Prediction*

---

**Description**

Takes a fitted [bamlss](#) object and computes predictions. Predictions can be based on estimated parameters of optimizer functions or on samples returned from sampler functions. It is possible to compute predictions on multiple cores using the [parallel](#) and to chunk predictions to save computation time and memory storage. Predictions can be computed for full distributional parameters or specific model terms. If a `link{bamlss}` model was fitted on multiple cores, i.e., the samples are provided as `link{mcmc.list}` where each list entry represents samples from one core, function `predict.bamlss()` computes combined predictions based on samples of all cores.

**Usage**

```
## S3 method for class 'bamlss'
predict(object, newdata, model = NULL, term = NULL,
  match.names = TRUE, intercept = TRUE, type = c("link", "parameter"),
  FUN = function(x) { mean(x, na.rm = TRUE) }, trans = NULL,
  what = c("samples", "parameters"), nsamps = NULL,
  verbose = FALSE, drop = TRUE,
  cores = NULL, chunks = 1, ...)
```

**Arguments**

|             |                                                                                                                                                                                                                                                                                                                                |
|-------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| object      | An object of class "bamlss"                                                                                                                                                                                                                                                                                                    |
| newdata     | A data frame or list containing the values of the model covariates at which predictions are required. Note that depending on argument term, only covariates that are needed by the corresponding model terms need to be supplied.                                                                                              |
| model       | Character or integer, specifies the model for which predictions should be computed.                                                                                                                                                                                                                                            |
| term        | Character or integer, specifies the model terms for which predictions are required. Note that, e.g., term = c("s(x1)", "x2") will compute the combined prediction $s(x1) + x2$ .                                                                                                                                               |
| match.names | Should partial string matching be used to select the terms for prediction. Note that, e.g., term = "x1" will select all terms including "x1" if match.names = TRUE.                                                                                                                                                            |
| intercept   | Should the intercept be included?                                                                                                                                                                                                                                                                                              |
| type        | If type = "link" the predictor of the corresponding model is returned. If type = "parameter" predictions on the distributional parameter scale are returned.                                                                                                                                                                   |
| FUN         | A function that should be applied on the samples of predictors or parameters, depending on argument type.                                                                                                                                                                                                                      |
| trans       | A transformer function or named list of transformer functions that computes transformed predictions. If trans is a list, the list names must match the names of the parameters of the <a href="#">bamlss.family</a> .                                                                                                          |
| what        | Predictions can be computed from samples or estimated parameters of optimizer functions. If no samples are available the default is to use estimated parameters.                                                                                                                                                               |
| nsamps      | If the fitted <a href="#">bamlss</a> object contains samples of parameters, computing predictions may take quite some time. Therefore, to get a first feeling it can be useful to compute predictions only based on nsamps samples, i.e., nsamps specifies the number of samples which are extracted on equidistant intervals. |
| verbose     | If predictions are chunked, information on the prediction process can be printed.                                                                                                                                                                                                                                              |
| drop        | If predictions for only one model are returned, the list structure is dropped.                                                                                                                                                                                                                                                 |
| cores       | Specifies the number of cores that should be used for prediction. Note that this functionality is based on the <a href="#">parallel</a> package.                                                                                                                                                                               |
| chunks      | Should computations be split into chunks? Prediction is then processed sequentially.                                                                                                                                                                                                                                           |
| ...         | Arguments passed to prediction functions that are part of a <a href="#">bamlss.family</a> object, i.e., the objects has a \$predict() function that should be used instead.                                                                                                                                                    |



**Value**

Depending on arguments model, FUN and the structure of the `bamlss` model, a list of predictions or simple vectors or matrices of predictions.

**See Also**

`link{bamlss}`, `fitted.bamlss`.

**Examples**

```
## Not run: ## Generate some data.
d <- GAMart()

## Model formula.
f <- list(
  num ~ s(x1) + s(x2) + s(x3) + te(lon,lat),
  sigma ~ s(x1) + s(x2) + s(x3) + te(lon,lat)
)

## Estimate model.
b <- bamlss(f, data = d)

## Predictions.
p <- predict(b)
str(b)

## Prediction for "mu" model and term "s(x2)".
p <- predict(b, model = "mu", term = "s(x2)")

## Plot effect
plot2d(p ~ x2, data = d)

## Same for "sigma" model.
p <- predict(b, model = "sigma", term = "s(x2)")
plot2d(p ~ x2, data = d)

## Prediction for "mu" model and term "s(x1)" + "s(x2)"
## without intercept.
p <- predict(b, model = "mu", term = c("s(x1)", "s(x2)"),
  intercept = FALSE)

## Prediction based on quantiles.
p <- predict(b, model = "mu", term = "s(x2)", FUN = c95)
plot2d(p ~ x2, data = d)

## Extract samples of predictor for "s(x2)".
p <- predict(b, model = "mu", term = "s(x2)",
  intercept = FALSE, FUN = function(x) { x })
print(dim(p))
plot2d(p ~ x2, data = d, col.lines = rgb(0.1, 0.1, 0.1, alpha = 0.1))

## Or using specific combinations of terms.
```

```

p <- predict(b, model = "mu", term = c("s(x2)", "te(lon,lat)"),
  intercept = FALSE, FUN = function(x) { x })
head(p)

## Prediction using new data.
## Only need x3 data when predicting
## for s(x3).
nd <- data.frame("x3" = seq(0, 1, length = 100))
nd <- cbind(nd, predict(b, newdata = nd, term = "s(x3)"))
print(head(nd))
plot2d(mu ~ x3, data = nd)
plot2d(sigma ~ x3, data = nd)

## End(Not run)

```

---

randomize

*Transform Smooth Constructs to Random Effects*


---

### Description

The transformer function takes a `bamlss.frame` object and transforms all `smooth.constructs` into a random effects representation. Note that this is only possible for smooth terms with a single smoothing variance. The function is based on function `smooth2random`.

### Usage

```

trans_random(x)
randomize(x)

```

### Arguments

`x` Object returned from function `bamlss.frame`.

### Details

The decomposition is achieved by a spectral decomposition of the penalty and design matrix by finding a basis of the null space of the penalty matrix. This feature is used, e.g., for the `JAGS` sampler function. For more details see also `jagam`.

### Value

A transformed `bamlss.frame`. To each `smooth.construct` model term an element named "Xf", the fixed effects design matrix, and an element "rand\$Xr", the random effects design matrix, is added. In addition, for re-transforming parameters elements "trans.U" and "trans.D" are supplied. See also function `smooth2random`.

## References

Fahrmeir L, Kneib T, Lang S, Marx B (2013). Regression - Models, Methods and Applications. Springer-Verlag, Berlin. ISBN 978-3-642-34332-2.

Wood S.N. (2006). Generalized Additive Models: An Introduction with R. Chapman and Hall/CRC.

## See Also

[bamlss.frame](#), [bamlss](#), [smooth2random](#).

## Examples

```
## Simulate data.
d <- GAMart()

## Create a "bamlss.frame".
bf <- bamlss.frame(num ~ s(x1) + s(x2) + s(x3) + s(lon,lat), data = d)

## Structure of the "s(x1)" smooth.construct.
str(bf$x$mu$smooth.construct[["s(x1)"]])

## Transform.
bf <- randomize(bf)

## New structure adding fixed
## and random effect matrices.
str(bf$x$mu$smooth.construct[["s(x1)"]])
```

---

 rb

*Random Bits for BAMLSS*


---

## Description

This smooth constructor implements random bits model terms. Note that this is experimental.

## Usage

```
## Linear smooth constructor.
rb(..., k = 50)

## For mgcv.
## S3 method for class 'randombits.smooth.spec'
smooth.construct(object, data, knots, ...)
```

**Arguments**

... For function `rb()` a formula of the type  $\sim x_1 + x_2 + x_3$  that specifies the covariates that should be modeled.

k Integer, number of random bit columns in the design matrix.

object, data, knots See [smooth.construct](#).

**Value**

Function `rb()`, similar to function `s` a simple smooth specification object.

**See Also**

[bamlss](#), [predict.bamlss](#), [bfit](#), [boost](#)

**Examples**

```
## Not run: ## Simulate data.
set.seed(123)
d <- GAMart()

## Estimate model.
f <- num ~ rb(x1) + rb(x2) + rb(x3) + rb(~lon+lat)

b <- bamlss(f, data = d)

plot(b)

## End(Not run)
```

---

residuals.bamlss

*Compute BAMLSS Residuals*

---

**Description**

Function to compute quantile and response residuals.

**Usage**

```
## S3 method for class 'bamlss'
residuals(object, type = c("quantile", "response"),
  nsamps = NULL, ...)

## S3 method for class 'bamlss.residuals'
plot(x, which = c("hist-resid", "qq-resid", "wp"),
  spar = TRUE, ...)
```

**Arguments**

|        |                                                                                                                                                                                                                                                                                                                                                   |
|--------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| object | An object of class "bamlss".                                                                                                                                                                                                                                                                                                                      |
| type   | The type of residuals wanted, possible types are "quantile" residuals and "response" residuals.                                                                                                                                                                                                                                                   |
| nsamps | If the fitted <code>bamlss</code> object contains samples of parameters, computing residuals may take quite some time. Therefore, to get a first feeling it can be useful to compute residuals only based on <code>nsamps</code> samples, i.e., <code>nsamps</code> specifies the number of samples which are extracted on equidistant intervals. |
| x      | Object returned from function <code>residuals.bamlss()</code> .                                                                                                                                                                                                                                                                                   |
| which  | Should a histogram with kernel density estimates be plotted, a qq-plot or a worm plot?                                                                                                                                                                                                                                                            |
| spar   | Should graphical parameters be set by the plotting function?                                                                                                                                                                                                                                                                                      |
| ...    | For function <code>residuals.bamlss()</code> arguments passed to possible <code>\$residuals()</code> functions that may be part of a <code>bamlss.family</code> . For function <code>plot.bamlss.residuals()</code> arguments passed to function <code>hist.default</code> and <code>qqnorm.default</code> .                                      |

**Details**

Response residuals are the raw residuals, i.e., the response data minus the fitted distributional mean. If the `bamlss.family` object contains a function `$mu(par, ...)`, then raw residuals are computed with  $y - \mu(\text{par})$  where `par` is the named list of fitted values of distributional parameters. If `$mu(par, ...)` is missing, then the fitted values of the first distributional parameter are used.

Randomized quantile residuals are based on the cumulative distribution function of the `bamlss.family` object, i.e., the `$p(y, par, ...)` function.

**Value**

A vector of residuals.

**References**

Dunn P. K., and Smyth G. K. (1996). Randomized Quantile Residuals. *Journal of Computational and Graphical Statistics* **5**, 236–244.

van Buuren S., and Fredriks M. (2001) Worm Plot: Simple Diagnostic Device for Modelling Growth Reference Curves. *Statistics in Medicine*, **20**, 1259–1277

**See Also**

`bamlss`, `predict.bamlss`, `fitted.bamlss`.

**Examples**

```
## Not run: ## Generate data.
d <- GAMart()

## Estimate models.
b1 <- bamlss(num ~ s(x1), data = d)
```

```
b2 <- bamlss(num ~ s(x1) + s(x2) + s(x3), data = d)

## Extract quantile residuals.
e1 <- residuals(b1, type = "quantile")
e2 <- residuals(b2, type = "quantile")

## Plots.
plot(e1)
plot(e2)

## End(Not run)
```

---

|               |                                                                         |
|---------------|-------------------------------------------------------------------------|
| response_name | <i>Extract the response name of a <code>bamlss.frame</code> object.</i> |
|---------------|-------------------------------------------------------------------------|

---

## Description

This is a small helper function to quickly extract the response name(s) of an object of class "bamlss.frame" or "bamlss".

## Usage

```
response_name(object, ...)
```

## Arguments

|        |                                                |
|--------|------------------------------------------------|
| object | An object of class "bamlss.frame" or "bamlss". |
| ...    | Not used.                                      |

## See Also

[bamlss](#), [bamlss.frame](#)

## Examples

```
## Simulate some data.
d <- GAMart()

## Create a bamlss.frame.
bf <- bamlss.frame(num ~ s(x1) + s(x2) + s(x3), data = d)

## Extract the response name.
response_name(bf)
```

---

`results.bamlss.default`*Compute BAMLSS Results for Plotting and Summaries*

---

## Description

The results function combines estimated parameters and/or samples with the `bamlss.frame` and computes the data that can be used, e.g., for creating effect plots or summary statistics. The function is usually used internally within `bamlss`. The object returned is of class "bamlss.results", which has a plotting method, see `plot.bamlss.results`.

## Usage

```
results.bamlss.default(x, what = c("samples", "parameters"),
  grid = -1, nsamps = NULL, burnin = NULL, thin = NULL, ...)
```

## Arguments

|                     |                                                                                                                                                                                                                                                                            |
|---------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>x</code>      | A <code>bamlss.frame</code> which has estimated parameters or samples. See also <code>bfit</code> and <code>GCMC</code> .                                                                                                                                                  |
| <code>what</code>   | Should the results data be prepared using estimated parameters or samples?                                                                                                                                                                                                 |
| <code>grid</code>   | Integer, sets the number of grid points for univariate functions to be used for creating results data, e.g., for plotting. This is more efficient when using data sets with a large number of unique covariate values. If negative suitable defaults are chosen.           |
| <code>nsamps</code> | Integer, if results are computed using parameter samples, this argument controls the number of samples that should be used, e.g., if <code>nsamps = 100</code> only 100 samples with equidistant intervals are selected. Basically similar to argument <code>thin</code> . |
| <code>burnin</code> | Integer, sets the number of samples that should be dropped from the beginning of the MCMC chain when creating results.                                                                                                                                                     |
| <code>thin</code>   | Integer, should the MCMC chain be thinned additionally?                                                                                                                                                                                                                    |
| <code>...</code>    | Currently not used.                                                                                                                                                                                                                                                        |

## Value

An object of class "bamlss.results".

## See Also

`plot.bamlss.results`, `bamlss`.

**Examples**

```
## Not run: ## Simulate data.
d <- GAMart()

## Estimate model with no results.
b <- bamlss(num ~ s(x1) + s(x2) + s(x3),
  data = d, results = FALSE)

## Compute model results
a <- results.bamlss.default(b)

## Plot results for smooth terms.
plot(a)

## End(Not run)
```

---

rmf

*Remove Special Characters*

---

**Description**

A simple helper function that removes special characters from a character string.

**Usage**

```
rmf(x)
```

**Arguments**

x                    A character string.

**Value**

A character string with special characters removed.

**Examples**

```
rmf("ba*&m^1$$:s.s")
```



**Description**

This is a simple wrapper function to define special smooth terms in BAMLSS formulae. The function calls the smooth term constructor function `s`. The return value of `s` is only slightly modified, such that function `bamlss.frame` identifies this term as a special term and uses the appropriate (internal) infrastructures.

This structure is useful when the model term structure is, e.g., not a linear combination of a design matrix and coefficients. See the example section of function `bfit` on how to use this setup.

**Usage**

```
s2(...)
```

**Arguments**

... Arguments passed to function `s`.

**Value**

Slightly modified return value of function `s`.

**See Also**

`bamlss`, `bamlss.frame`, `bamlss.formula`, `opt_bfit`

**Examples**

```
print(names(s(x)))
print(names(s2(x)))
```

**Description**

Generic function to extract samples from objects.

**Usage**

```
## Generic.
samples(object, ...)

## Method for "bamlss" objects.
## S3 method for class 'bamlss'
samples(object, model = NULL, term = NULL,
  combine = TRUE, drop = TRUE, burnin = NULL,
  thin = NULL, coef.only = FALSE, ...)
```

**Arguments**

|           |                                                                                                                                                    |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------|
| object    | An object for which samples should be extracted.                                                                                                   |
| model     | Character or integer, specifies the model for which samples should be extracted.                                                                   |
| term      | Character or integer, specifies the term for which samples should be extracted.                                                                    |
| combine   | Samples stored as a <code>mcmc.list</code> , e.g., when a model is estimated on multiple cores, can be combined into one large sample matrix.      |
| drop      | If there is only one model for which samples should be extracted, should the list structure be dropped?                                            |
| burnin    | Integer, specifies the number of samples that should be withdrawn as a burn-in phase.                                                              |
| thin      | Integer, specifies the step length of samples that should be extracted, e.g., <code>thin = 10</code> mean that only every 10th sample is returned. |
| coef.only | Logical, should only samples of model coefficients be returned?                                                                                    |
| ...       | Other arguments.                                                                                                                                   |

**See Also**

[bamlss](#).

**Examples**

```
## Not run: ## Generate data.
d <- GAMart()

## Estimate model.
b <- bamlss(num ~ s(x1) + s(x2) + s(x3), data = d)

## Extract samples for "s(x2)".
sa <- samples(b, term = "s(x2)")
head(sa)

## Trace plot.
plot(sa)

## End(Not run)
```

---

 samplestats

*Sampling Statistics*


---

### Description

The function computes the average the log-likelihood, log-posterior, the deviance information criterion and estimated degrees of freedom from samples of, e.g., a [bamlss](#) object.

### Usage

```
samplestats(samples, x = NULL, y = NULL,
            family = NULL, logLik = FALSE, ...)
```

### Arguments

|         |                                                                          |
|---------|--------------------------------------------------------------------------|
| samples | An object of class "mcmc.list" or "bamlss" which contains MCMC samples.  |
| x       | The x list as returned by function <a href="#">bamlss.frame</a> .        |
| y       | The model response, as returned by function <a href="#">bamlss.frame</a> |
| family  | A <a href="#">bamlss.family</a> object.                                  |
| logLik  | Logical, should the log-likelihood be computed, may take some time!      |
| ...     | Currently not used.                                                      |

### Details

If the log-likelihood is not available in the samples, the function tries to compute the information. Depending on the complexity of the model, this may take some time. Computations are based on the `$d()` or `$loglik()` function of the [bamlss.family](#) object.

If a [bamlss.family](#) object contains a function `$p2d()` or `$p2loglik()`, which computes the log-likelihood from parameters, these functions are used for computation.

### Value

A list with the following entries (if available):

|         |                                     |
|---------|-------------------------------------|
| logLik  | The average log-likelihood.         |
| logPost | The average log-posterior.          |
| DIC     | The deviance information criterion. |
| pd      | The estimated degrees of freedom.   |

### See Also

[bamlss](#)

**Examples**

```
## Not run: ## Generate some data.
d <- GAMart()

## Estimate model without sampling statistics
b <- bamlss(num ~ s(x1) + s(x2) + s(x3) + te(lon,lat),
  data = d, samplestats = FALSE)

## Note: needs the $d() or $loglik() function in the family!
names(family(b))

## Compute sampling statistics.
samplestats(b)

## End(Not run)
```

---

sam\_BayesX

---

*Markov Chain Monte Carlo for BAMLSS using **BayesX***


---

**Description**

This sampler function for BAMLSS is an interface to the **BayesX** (<https://www.uni-goettingen.de/de/bayesx/550513>. command-line binary from R. The sampler is based on the command line version and functions provided in the **BayesXsrc** package, which can be installed using function `get_BayesXsrc()`.

**Usage**

```
## Sampler functions:
sam_BayesX(x, y, family, start = NULL, weights = NULL, offset = NULL,
  data = NULL, control = BayesX.control(...), ...)

BayesX(x, y, family, start = NULL, weights = NULL, offset = NULL,
  data = NULL, control = BayesX.control(...), ...)

## Sampler control:
BayesX.control(n.iter = 1200, thin = 1, burnin = 200,
  seed = NULL, predict = "light", model.name = "bamlss",
  data.name = "d", prg.name = NULL, dir = NULL,
  verbose = FALSE, show.prg = TRUE, modeonly = FALSE, ...)

## Special BayesX smooth term constructor.
sx(x, z = NULL, bs = "ps", by = NA, ...)

## Special BayesX tensor product smooth term constructor.
tx(..., bs = "ps", k = -1,
  ctr = c("center", "main", "both", "both1", "both2",
    "none", "meanf", "meanfd", "meansimple", "nullspace"),
  xt = NULL, special = TRUE)
```

```

tx2(...)
tx3(..., bs = "ps", k = c(10, 5),
  ctr = c("main", "center"),
  xt = NULL, special = TRUE)
tx4(..., ctr = c("center", "main", "both", "both1", "both2"))

## Smooth constructors and predict matrix.
## S3 method for class 'tensorX.smooth.spec'
smooth.construct(object, data, knots, ...)
## S3 method for class 'tensorX.smooth'
Predict.matrix(object, data)
## S3 method for class 'tensorX3.smooth.spec'
smooth.construct(object, data, knots, ...)
## S3 method for class 'tensorX3.smooth'
Predict.matrix(object, data)

## Family object for quantile regression with BayesX.
quant_bamlss(prob = 0.5)

## Download the newest version of BayesXsrc.
get_BayesXsrc(dir = NULL, install = TRUE)

```

## Arguments

|         |                                                                                                                                                                                                                                                                                                      |
|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| x       | For function <code>BayesX()</code> the x list, as returned from function <code>bamlss.frame</code> , holding all model matrices and other information that is used for fitting the model. For function <code>sx()</code> arguments x and z specify the variables the smooth should be a function of. |
| y       | The model response, as returned from function <code>bamlss.frame</code> .                                                                                                                                                                                                                            |
| z       | Second variable in a <code>sx()</code> term.                                                                                                                                                                                                                                                         |
| family  | A <b>bamlss</b> family object, see <code>family.bamlss</code> .                                                                                                                                                                                                                                      |
| start   | A named numeric vector containing possible starting values, the names are based on function <code>parameters</code> .                                                                                                                                                                                |
| weights | Prior weights on the data, as returned from function <code>bamlss.frame</code> .                                                                                                                                                                                                                     |
| offset  | Can be used to supply model offsets for use in fitting, returned from function <code>bamlss.frame</code> .                                                                                                                                                                                           |
| data    | The model frame that should be used for modeling. Note that argument data needs not to be specified when the <code>BayesX()</code> sampler function is used with <code>bamlss</code> . For the smooth constructor for <code>tx()</code> terms, see function <code>smooth.construct</code> .          |
| control | List of control arguments to be send to <b>BayesX</b> . See below.                                                                                                                                                                                                                                   |
| n.iter  | Sets the number of MCMC iterations.                                                                                                                                                                                                                                                                  |
| thin    | Defines the thinning parameter for MCMC simulation. E.g., <code>thin = 10</code> means, that only every 10th sampled parameter will be stored.                                                                                                                                                       |
| burnin  | Sets the burn-in phase of the sampler, i.e., the number of starting samples that should be removed.                                                                                                                                                                                                  |

|               |                                                                                                                                                                                                                                                                                                                                                                                                  |
|---------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| seed          | Sets the seed.                                                                                                                                                                                                                                                                                                                                                                                   |
| predict       | Not supported at the moment, do not modify!                                                                                                                                                                                                                                                                                                                                                      |
| model.name    | The name that should be used for the model when calling <b>BayesX</b> .                                                                                                                                                                                                                                                                                                                          |
| data.name     | The name that should be used for the data set when calling <b>BayesX</b> .                                                                                                                                                                                                                                                                                                                       |
| prg.name      | The name that should be used for the .prg file that is send to <b>BayesX</b> .                                                                                                                                                                                                                                                                                                                   |
| dir           | Specifies the directory where <b>BayesX</b> should store all output files. For function <code>get_BayesXsrc()</code> , the directory where <b>BayesXsrc</b> should be stored.                                                                                                                                                                                                                    |
| verbose       | Print information during runtime of the algorithm.                                                                                                                                                                                                                                                                                                                                               |
| show.prg      | Show the <b>BayesX</b> .prg file.                                                                                                                                                                                                                                                                                                                                                                |
| modeonly      | Should only the posterior mode be compute, note that this is done using fixed smoothing parameters/variances.                                                                                                                                                                                                                                                                                    |
| bs            | A <a href="#">character</a> string, specifying the basis/type which is used for this model term.                                                                                                                                                                                                                                                                                                 |
| by            | A by variable for varying coefficient model terms.                                                                                                                                                                                                                                                                                                                                               |
| k             | The dimension(s) of the bases used to represent the <code>tx()</code> smooth term.                                                                                                                                                                                                                                                                                                               |
| ...           | Not used in <code>BayesX.control</code> . For function <code>sx()</code> any extra arguments that should be passed to <b>BayesX</b> for this model term can be specified here. For function <code>tx()</code> , all variables the smooth should be a function of are specified here. For function <code>sam_BayesX()</code> all arguments that should be passed to <code>BayesX.control</code> . |
| ctr           | Specifies the type of constraints that should be applied. "main", both main effects should be removed; "both", both main effects and varying effects should be removed; "none", no constraint should be applied.                                                                                                                                                                                 |
| xt            | A list of extra arguments to be passed to <b>BayesX</b> .                                                                                                                                                                                                                                                                                                                                        |
| special       | Should the <code>tx()</code> model term be treated as a special smooth. This must be set to TRUE if using the <code>sam_BayesX</code> sampler and should be set to FALSE, e.g., when using the <code>sam_GMCMC</code> sampler.                                                                                                                                                                   |
| object, knots | See, function <code>smooth.construct</code> .                                                                                                                                                                                                                                                                                                                                                    |
| prob          | Numeric, specifies the quantile to be modeled, see the examples.                                                                                                                                                                                                                                                                                                                                 |
| install       | Should package <b>BayesXsrc</b> be installed?                                                                                                                                                                                                                                                                                                                                                    |

## Details

Function `sam_BayesX()` writes a **BayesX** .prg file and processes the data. Then, the function call the **BayesX** binary via function `run.bayesx`. After the **BayesX** sampler has finished, the function reads back in all the parameter samples that can then be used for further processing within `bamlss`, i.a.

The smooth term constructor functions `s` and `te` can be used with the `sam_BayesX()` sampler. When using `te` note that only one smoothing variance is estimated by **BayesX**.

For anisotropic penalties use function `tx()` and `tx3()`, the former currently supports smooth functions of two variables, while `tx3()` is supposed to model space-time interactions. Note that in `tx3()` the first variable represents time and the 2nd and 3rd variable the coordinates in space.

**Value**

Function `sam_BayesX()` returns samples of parameters. The samples are provided as a `mcmc` matrix.

Function `BayesX.control()` returns a list with control arguments for **BayesX**.

Function `sx()` a list of class `"xx.smooth.spec"` and `"no.mgcv"`, where `"xx"` is a basis/type identifying code given by the `bs` argument.

Function `tx()` and `tx2()` a list of class `tensorX.smooth.spec`.

**Note**

Note that this interface is still experimental and needs the newest version of the **BayesX** source code, which is not yet part of the **BayesXsrc** package on CRAN. The newest version can be installed with function `get_BayesXsrc`. Note that the function assumes that `sh`, subversion (`svn`) and `R` can be run from the command line!

Note that for setting up a new family object to be used with `sam_BayesX()` additional information needs to be supplied. The extra information must be placed within the family object in a named list element named `"bayesx"`. For each parameter of the distribution a character string with the corresponding **BayesX** family name and the equation type must be supplied. See, e.g., the R code of `gaussian_bamlss` how the setup works.

For function `sx()` the following basis types are currently supported:

- `"ps"`: P-spline with second order difference penalty.
- `"mrf"`: Markov random fields: Defines a Markov random field prior for a spatial covariate, where geographical information is provided by a map object in boundary or graph file format (see function `read.bnd`, `read.gra` and `shp2bnd`), as an additional argument named `map`.
- `"re"`: Gaussian i.i.d. Random effects of a unit or cluster identification covariate.

Function `tx()` currently supports smooth terms with two variables.

**See Also**

`bamlss`, `bamlss.frame`

**Examples**

```
## Get newest version of BayesXsrc.
## Note: needs sh, svn and R build tools!
## get_BayesXsrc()
## Not run: if(require("BayesXsrc")) {
  ## Simulate some data
  set.seed(123)
  d <- GAMart()

  ## Estimate model with BayesX. Note
  ## that BayesX computes starting values, so
  ## these are not required by some optimizer function
  ## in bamlss()
  b1 <- bamlss(num ~ s(x1) + s(x2) + s(x3) + s(lon,lat),
    data = d, optimizer = FALSE, sampler = sam_BayesX)
```

```

plot(b1)

## Same model with anisotropic penalty.
b2 <- bamlss(num ~ s(x1) + s(x2) + s(x3) + tx(lon,lat),
  data = d, optimizer = FALSE, sampler = sam_BayesX)

plot(b2)

## Quantile regression.
b3_0.1 <- bamlss(num ~ s(x1) + s(x2) + s(x3) + tx(lon,lat),
  data = d, optimizer = FALSE, sampler = sam_BayesX,
  family = gF("quant", prob = 0.1))

b3_0.9 <- bamlss(num ~ s(x1) + s(x2) + s(x3) + tx(lon,lat),
  data = d, optimizer = FALSE, sampler = sam_BayesX,
  family = gF("quant", prob = 0.9))

## Predict quantiles.
p_0.1 <- predict(b3_0.1, term = "s(x2)")
p_0.9 <- predict(b3_0.9, term = "s(x2)")

## Plot.
plot2d(p_0.1 + p_0.9 ~ x2, data = d)
}

## End(Not run)

```

---

sam\_Cox

*Cox Model Markov Chain Monte Carlo*


---

## Description

This sampler function implements a derivative based MCMC algorithm for flexible Cox models with structured additive predictors.

## Usage

```

sam_Cox(x, y, family, start, weights, offset,
  n.iter = 1200, burnin = 200, thin = 1,
  verbose = TRUE, digits = 4, step = 20, ...)

```

```

cox_mcmc(x, y, family, start, weights, offset,
  n.iter = 1200, burnin = 200, thin = 1,
  verbose = TRUE, digits = 4, step = 20, ...)

```

## Arguments

x                    The x list, as returned from function [bamlss.frame](#) and transformed by function [surv\\_transform](#), holding all model matrices and other information that is used for fitting the model.



|         |                                                                                                                                                |
|---------|------------------------------------------------------------------------------------------------------------------------------------------------|
| y       | The model response, as returned from function <code>bamlss.frame</code> .                                                                      |
| family  | A <b>bamlss</b> family object, see <code>family.bamlss</code> . In this case this is the <code>cox_bamlss</code> family object.                |
| start   | A named numeric vector containing possible starting values, the names are based on function <code>parameters</code> .                          |
| weights | Prior weights on the data, as returned from function <code>bamlss.frame</code> .                                                               |
| offset  | Can be used to supply model offsets for use in fitting, returned from function <code>bamlss.frame</code> .                                     |
| n.iter  | Sets the number of MCMC iterations.                                                                                                            |
| burnin  | Sets the burn-in phase of the sampler, i.e., the number of starting samples that should be removed.                                            |
| thin    | Defines the thinning parameter for MCMC simulation. E.g., <code>thin = 10</code> means, that only every 10th sampled parameter will be stored. |
| verbose | Print information during runtime of the algorithm.                                                                                             |
| digits  | Set the digits for printing when <code>verbose = TRUE</code> .                                                                                 |
| step    | How many times should algorithm runtime information be printed, divides <code>n.iter</code> .                                                  |
| ...     | Currently not used.                                                                                                                            |

### Details

The sampler uses derivative based proposal functions to create samples of parameters. For time-dependent functions the proposals are based on one Newton-Raphson iteration centered at the last state, while for the time-constant functions proposals can be based on iteratively reweighted least squares (IWLS), see also function `GMCMC`. The integrals that are part of the time-dependent function updates are solved numerically. In addition, smoothing variances are sampled using slice sampling.

### Value

The function returns samples of parameters. The samples are provided as a `mcmc` matrix.

### References

Umlauf N, Klein N, Zeileis A (2016). Bayesian Additive Models for Location Scale and Shape (and Beyond). (*to appear*)

### See Also

`opt_Cox`, `cox_bamlss`, `surv_transform`, `simSurv`, `bamlss`

### Examples

```
## Not run: library("survival")
set.seed(123)

## Simulate survival data.
d <- simSurv(n = 500)
```

```

## Formula of the survival model, note
## that the baseline is given in the first formula by s(time).
f <- list(
  Surv(time, event) ~ s(time) + s(time, by = x3),
  gamma ~ s(x1) + s(x2)
)

## Cox model with continuous time.
## Note the the family object cox_bamlss() sets
## the default optimizer and sampler function!
## First, posterior mode estimates are computed
## using function opt_Cox(), afterwards the
## sampler sam_Cox() is started.
b <- bamlss(f, family = "cox", data = d)

## Plot estimated effects.
plot(b)

## End(Not run)

```

---

sam\_GMCMC

*General Markov Chain Monte Carlo for BAMLSS*


---

## Description

These functions provide a quite general infrastructure for sampling BAMLSS. The default proposal function is based on iteratively weighted least squares (IWLS), however, each model term may have a different updating function, see the details.

## Usage

```

## Sampler functions:
sam_GMCMC(x, y, family, start = NULL, weights = NULL, offset = NULL,
  n.iter = 1200, burnin = 200, thin = 1, verbose = TRUE,
  step = 20, propose = "iwlsC_gp", chains = NULL, ...)

GMCMC(x, y, family, start = NULL, weights = NULL, offset = NULL,
  n.iter = 1200, burnin = 200, thin = 1, verbose = TRUE,
  step = 20, propose = "iwlsC_gp", chains = NULL, ...)

## Propose functions:
GMCMC_iwls(family, theta, id, eta, y, data,
  weights = NULL, offset = NULL, ...)
GMCMC_iwlsC(family, theta, id, eta, y, data,
  weights = NULL, offset = NULL, zworking, resids, rho, ...)
GMCMC_iwlsC_gp(family, theta, id, eta, y, data,
  weights = NULL, offset = NULL, zworking, resids, rho, ...)
GMCMC_slice(family, theta, id, eta, y, data, ...)

```

**Arguments**

|          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| x        | For function <code>bf.it()</code> the x list, as returned from function <code>bamlss.frame</code> , holding all model matrices and other information that is used for fitting the model. For the updating functions an object as returned from function <code>smooth.construct</code> or <code>smoothCon</code> .                                                                                                                                                                                                                                          |
| y        | The model response, as returned from function <code>bamlss.frame</code> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| family   | A <b>bamlss</b> family object, see <code>family.bamlss</code> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| start    | A named numeric vector containing possible starting values, the names are based on function <code>parameters</code> .                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| weights  | Prior weights on the data, as returned from function <code>bamlss.frame</code> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| offset   | Can be used to supply model offsets for use in fitting, returned from function <code>bamlss.frame</code> .                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| n.iter   | Sets the number of MCMC iterations.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| burnin   | Sets the burn-in phase of the sampler, i.e., the number of starting samples that should be removed.                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| thin     | Defines the thinning parameter for MCMC simulation. E.g., <code>thin = 10</code> means, that only every 10th sampled parameter will be stored.                                                                                                                                                                                                                                                                                                                                                                                                             |
| verbose  | Print information during runtime of the algorithm.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| step     | How many times should algorithm runtime information be printed, divides <code>n.iter</code> .                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| propose  | Sets the propose function for model terms, e.g. for a term $s(x)$ in the model formula. Per default this is set to "iwlsC", a character pointing to the set of propose functions, see above. Other options are "iwls" and "slice", however, this is more experimental and should not be set by the user. Another option is to pass a full propose function which should be used for each model term, the structure of propose functions is described in the details below. Model terms may also have different propose functions, see the example section. |
| chains   | How many chains should be started? Chains a sampled sequentially!                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| theta    | The current state of parameters, provided as a named list. The first level represents the parameters of the distribution, the second level the parameters of the model terms. E.g., using the <code>gaussian_bamlss</code> family object <code>theta[["mu"]][["s(x)"]]</code> extracts the current state of a model term "s(x)" of the "mu" parameter. Extraction is done with the <code>id</code> argument.                                                                                                                                               |
| id       | The parameter identifier, a character vector of length 2. The first character specifies the current distributional parameter, the second the current model term.                                                                                                                                                                                                                                                                                                                                                                                           |
| eta      | The current value of the predictors, provided as a named list, one list entry for each parameter. The names correspond to the parameter names in the family object, see <code>family.bamlss</code> . E.g., when using the <code>gaussian_bamlss</code> family object, the current values for the mean can be extracted by <code>eta\\$\mu</code> and for the standard deviation by <code>eta\\$\sigma</code> .                                                                                                                                             |
| data     | An object as returned from function <code>smooth.construct</code> or <code>smoothCon</code> . The object is preprocessed by function <code>bamlss.engine.setup</code> .                                                                                                                                                                                                                                                                                                                                                                                    |
| zworking | Preinitialized numeric vector of length(y), only for internal usage.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| resids   | Preinitialized numeric vector of length(y), only for internal usage.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

rho                    An environment, only for internal usage.  
 ...                    Arguments passed to function `bamlss.engine.setup` and to the propose functions.

### Details

The sampler function `sam_GMCMC()` cycles through all distributional parameters and corresponding model terms in each iteration of the MCMC chain. Samples of the parameters of a model term (e.g.,  $s(x)$ ) are generated by proposal functions, e.g. `GMCMC_iwls()`.

The default proposal function that should be used for all model terms is set with argument `propose`. For smooth terms, e.g. terms created with function `s`, if a valid propose function is supplied within the extra `xt` list, this propose function will be used. This way each model term may have its own propose function for creating samples of the parameters. See the example section.

The default proposal function `GMCMC_iwlsC_gp` allows for general priors for the smoothing variances and general penalty functions. Samples of smoothing variances are computed using slice sampling. Function `GMCMC_iwlsC` samples smoothing variances of univariate terms assuming an inverse gamma prior. Terms of higher dimensions use again slice sampling for creating samples of smoothing variances.

Function `GMCMC_iwls` is similar to function `GMCMC_iwlsC` but uses plain R code.

Function `GMCMC_slice` applies slice sampling also for the regression coefficients and is therefore relatively slow.

### Value

The function returns samples of parameters, depending on the return value of the propose functions other quantities can be returned. The samples are provided as a `mcmc` matrix. If `chains > 1`, the samples are provided as a `mcmc.list`.

### References

Umlauf N, Klein N, Zeileis A (2016). Bayesian Additive Models for Location Scale and Shape (and Beyond). *(to appear)*

### See Also

`bamlss`, `bamlss.frame`, `bamlss.engine.setup`, `set.starting.values`, `s2`

### Examples

```
## Not run: ## Simulated data example illustrating
## how to call the sampler function.
## This is done internally within
## the setup of function bamlss().
d <- GAMart()
f <- num ~ s(x1, bs = "ps")
bf <- bamlss.frame(f, data = d, family = "gaussian")

## First, find starting values with optimizer.
opt <- with(bf, bfit(x, y, family))
```

```
## Sample.
samps <- with(bf, sam_GMCMC(x, y, family, start = opt$parameters))
plot(samps)

## End(Not run)
```

---

sam\_JAGS

---

*Markov Chain Monte Carlo for BAMLSS using JAGS*


---

### Description

This sampler function for BAMLSS is an interface to the JAGS library using package [rjags](#). The function basically interprets the [bamlss.frame](#) into BUGS code, similar to the [jagam](#) function of package [mgcv](#). I.e., the function uses the random effects representation of smooth terms, see the transformer function [randomize](#) to generate the BUGS code.

Note that estimating BAMLSS with JAGS is not very efficient. Also note that this function is more experimental and support is only provided for a small number of [bamlss.family](#) objects.

Function `BUGSeta()` therefore computes the code and data for one parameter of the modeled distribution. Function `BUGSmodel()` then collects all parameter model code and data, which can be send to JAGS.

### Usage

```
## Sampler functions:
sam_JAGS(x, y, family, start = NULL,
  tdir = NULL, n.chains = 1, n.adapt = 100,
  n.iter = 4000, thin = 2, burnin = 1000,
  seed = NULL, verbose = TRUE, set.inits = TRUE,
  save.all = FALSE, modules = NULL, ...)

JAGS(x, y, family, start = NULL,
  tdir = NULL, n.chains = 1, n.adapt = 100,
  n.iter = 4000, thin = 2, burnin = 1000,
  seed = NULL, verbose = TRUE, set.inits = TRUE,
  save.all = FALSE, modules = NULL, ...)

## Function to interpret an additive predictor into BUGS code:
BUGSeta(x, id = NULL, ...)

## Function to interpret the full BAMLSS:
BUGSmodel(x, family, is.stan = FALSE, reference = NULL, ...)
```

### Arguments

x For function `sam_JAGS()` and `BUGSmodel()` the x list, as returned from function [bamlss.frame](#), holding all model matrices and other information that is used

|                        |                                                                                                                                                      |
|------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|
|                        | for fitting the model. For function <code>BUGSeta()</code> argument <code>x</code> is one element of the <code>x</code> object, i.e., one parameter. |
| <code>y</code>         | The model response, as returned from function <code>bamlss.frame</code> .                                                                            |
| <code>family</code>    | A <b>bamlss</b> family object, see <code>family.bamlss</code> .                                                                                      |
| <code>start</code>     | A named numeric vector containing possible starting values, the names are based on function <code>parameters</code> .                                |
| <code>tdir</code>      | The path to the temporary directory that should be used.                                                                                             |
| <code>n.chains</code>  | Specifies the number of sequential MCMC chains that should be run with JAGS.                                                                         |
| <code>n.adapt</code>   | Specifies the number of iterations that should be used as an initial adaptive phase.                                                                 |
| <code>n.iter</code>    | Sets the number of MCMC iterations.                                                                                                                  |
| <code>thin</code>      | Defines the thinning parameter for MCMC simulation. E.g., <code>thin = 10</code> means, that only every 10th sampled parameter will be stored.       |
| <code>burnin</code>    | Sets the burn-in phase of the sampler, i.e., the number of starting samples that should be removed.                                                  |
| <code>seed</code>      | Sets the seed.                                                                                                                                       |
| <code>verbose</code>   | Print information during runtime of the algorithm.                                                                                                   |
| <code>set.inits</code> | Should initial values of BAMLSS <code>parameters</code> be provided to JAGS, if available. Set in argument <code>start</code> .                      |
| <code>save.all</code>  | Should all JAGS files be saved in <code>tdir</code> .                                                                                                |
| <code>modules</code>   | Specify additional modules that should be loaded, see function <code>load.module</code> .                                                            |
| <code>id</code>        | Character, the current parameter name for which the BUGS code should be produced.                                                                    |
| <code>is.stan</code>   | Should the BUGS code be translated to STAN code. Note that this is only experimental.                                                                |
| <code>reference</code> | A character specifying a reference category, e.g., when fitting a multinomial model.                                                                 |
| <code>...</code>       | Currently not used.                                                                                                                                  |

### Value

Function `sam_JAGS()` returns samples of parameters. The samples are provided as a `mcmc` matrix. If `n.chains > 1`, the samples are provided as a `mcmc.list`.

Function `BUGSeta()` returns the BUGS model code and preprocessed data for one additive predictor. Function `BUGSmodel()` then combines all single BUGS code chunks and the data and creates the final BUGS model code that can be send to JAGS.

### Note

Note that for setting up a new family object to be used with `sam_JAGS()` additional information needs to be supplied. The extra information must be placed within the family object in an element named `"bugs"`. The following entries should be supplied within the `..$bugs` list:

- `"dist"`. The name of the distribution in BUGS/JAGS model language.

- "eta". The function that computes the BUGS code for one structured additive predictor. Function BUGSeta() is used per default.
- "model". The function that merges all single predictor BUGS model code and data. The default function is BUGSmodel().
- "reparam". A named vector of character strings that specify a re-parametrization.

See also the example code of [family.bamlss](#).

### See Also

[bamlss](#), [bamlss.frame](#), [bamlss.engine.setup](#), [set.starting.values](#), [bfit](#), [GMCMC](#)

### Examples

```
## Not run: ## Simulated data example illustrating
## how to call the sampler function.
## This is done internally within
## the setup of function bamlss().
d <- GAMart()
f <- num ~ s(x1, bs = "ps")
bf <- bamlss.frame(f, data = d, family = "gaussian")

## First, find starting values with optimizer.
opt <- with(bf, opt_bfit(x, y, family))

## Sample with JAGS.
if(require("rjags")) {
  samps <- with(bf, sam_JAGS(x, y, family, start = opt$parameters))
  plot(samps)

  b <- bamlss(f, data = d, family = "gaussian", sampler = sam_JAGS)
  plot(b)
}

## End(Not run)
```

### Description

This sampler function for BAMLSS uses estimated [parameters](#) and the Hessian information to create samples from a multivariate normal distribution. Note that smoothing variance uncertainty is not accounted for, therefore, the resulting credible intervals are most likely too narrow.

**Usage**

```
sam_MVNORM(x, y = NULL, family = NULL, start = NULL,
           n.samples = 500, hessian = NULL, ...)
```

```
MVNORM(x, y = NULL, family = NULL, start = NULL,
       n.samples = 500, hessian = NULL, ...)
```

**Arguments**

|           |                                                                                                                                                                                                                                                                      |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| x         | The x list, as returned from function <code>bamlss.frame</code> , holding all model matrices and other information that is used for fitting the model. Or an object returned from function <code>bamlss</code> .                                                     |
| y         | The model response, as returned from function <code>bamlss.frame</code> .                                                                                                                                                                                            |
| family    | A <code>bamlss</code> family object, see <code>family.bamlss</code> .                                                                                                                                                                                                |
| start     | A named numeric vector containing possible starting values, the names are based on function <code>parameters</code> .                                                                                                                                                |
| n.samples | Sets the number of samples that should be generated.                                                                                                                                                                                                                 |
| hessian   | The Hessian matrix that should be used. Note that the row and column names must be the same as the names of the <code>parameters</code> . If <code>hessian = NULL</code> the function uses <code>optim</code> to compute the Hessian if it is not provided within x. |
| ...       | Arguments passed to function <code>optim</code> .                                                                                                                                                                                                                    |

**Value**

Function `MVNORM()` returns samples of parameters. The samples are provided as a `mcmc` matrix.

**See Also**

`bamlss`, `bamlss.frame`, `bamlss.engine.setup`, `set.starting.values`, `opt_bfit`, `sam_GMCMC`

**Examples**

```
## Simulated data example illustrating
## how to call the sampler function.
## This is done internally within
## the setup of function bamlss().
d <- GAMart()
f <- num ~ s(x1, bs = "ps")
bf <- bamlss.frame(f, data = d, family = "gaussian")

## First, find starting values with optimizer.
o <- with(bf, opt_bfit(x, y, family))

## Sample.
samps <- with(bf, sam_MVNORM(x, y, family, start = o$parameters))
plot(samps)
```



---

|        |                                     |
|--------|-------------------------------------|
| scale2 | <i>Scaling Vectors and Matrices</i> |
|--------|-------------------------------------|

---

**Description**

The function scales numeric objects to specific ranges.

**Usage**

```
scale2(x, lower = -1.5, upper = 1.5)
```

**Arguments**

|       |                            |
|-------|----------------------------|
| x     | Numeric, vector or matrix. |
| lower | The upper range.           |
| upper | The lower range.           |

**Value**

A scaled numeric vector or matrix, scaled to the range provided in `lower` and `upper`.

**Examples**

```
set.seed(123)
x <- runif(5)
scale2(x, -1, 1)
scale2(x, 0, 10)
```

---

|       |                                                                 |
|-------|-----------------------------------------------------------------|
| simJM | <i>Simulate longitudinal and survival data for joint models</i> |
|-------|-----------------------------------------------------------------|

---

**Description**

Simulates longitudinal data with normal error and (Cox-type) survival times using the inversion method. The function `simJM()` is a wrapper specifying all predictors and the resulting data sets. The wrapper calls `rJM()` to sample the survival times, a modified version of `rSurvtime()` from the R package **CoxFlexBoost**.

**Usage**

```

simJM(nsub = 300, times = seq(0, 120, 1), probmiss = 0.75,
      long_setting = "functional",
      alpha_setting = if(nonlinear) "linear" else "nonlinear",
      dalpha_setting = "zero", sigma = 0.3, long_df = 6, tmax = NULL,
      seed = NULL, full = FALSE, file = NULL, nonlinear = FALSE,
      fac = FALSE)

rJM(hazard, censoring, x, r,
     subdivisions = 1000, tmin = 0, tmax,
     file = NULL, ...)

```

**Arguments**

|                |                                                                                                                                                                                                                                                                                                                                               |
|----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| nsub           | number of individuals for which longitudinal data and survival times should be simulated.                                                                                                                                                                                                                                                     |
| times          | vector of time points at which longitudinal measurements are "sampled".                                                                                                                                                                                                                                                                       |
| probmiss       | proportion of longitudinal measurements to be set to missing. Used to induce sparsity in the longitudinal measurements.                                                                                                                                                                                                                       |
| long_setting   | Specification of the longitudinal trajectories of the sampled subjects. Preset specifications are "linear", "nonlinear" and "functional". See Details.                                                                                                                                                                                        |
| alpha_setting  | specification of the association between survival and longitudinal. Preset specifications are "simple", "linear", "nonlinear" and "nonlinear2". See Details.                                                                                                                                                                                  |
| dalpha_setting | specification of the association between survival and the derivative of the longitudinal. Work in progress.                                                                                                                                                                                                                                   |
| sigma          | standard deviation of the normal error around the true longitudinal measurements.                                                                                                                                                                                                                                                             |
| long_df        | number of basis functions from which functional random intercepts are sampled.                                                                                                                                                                                                                                                                |
| tmax           | For function <code>simJM()</code> , longest possible survival time, observations are censored after that timepoint. Defaults to <code>max(times)</code> and should not be specified longer than <code>max(times)</code> for longitudinal setting "functional". For function <code>rJM()</code> , latest time point to sample a survival time. |
| seed           | numeric scalar setting the random seed.                                                                                                                                                                                                                                                                                                       |
| full           | logical indicating if only the longitudinal data set should be returned (FALSE) or additionally also the data for the survival part evaluated on a regular time grid and the longitudinal data set without longitudinal missings (TRUE).                                                                                                      |
| file           | name of the data file the generated data set should be stored into (e.g., "sim-data.RData") or NULL if the dataset should directly be returned in R.                                                                                                                                                                                          |
| nonlinear      | If set to TRUE, a nonlinear interaction between alpha and mu is simulated.                                                                                                                                                                                                                                                                    |
| fac            | If set to TRUE, a smooth interaction that varies by a factor is simulated.                                                                                                                                                                                                                                                                    |
| hazard         | complete hazard function to specify the joint model. Time must be the first argument.                                                                                                                                                                                                                                                         |
| censoring      | function to compute (random) censoring.                                                                                                                                                                                                                                                                                                       |

|              |                                                         |
|--------------|---------------------------------------------------------|
| x            | matrix of sampled covariate values.                     |
| r            | matrix of sampled random coefficients.                  |
| subdivisions | the maximum number of subintervals for the integration. |
| tmin         | earliest time point to sample a survival time.          |
| ...          | further arguments to be passed to hazard or censoring.  |

## Details

The function simulates longitudinal data basing on the given specification at given times. The full hazard is built from all joint model predictors  $\eta_\mu, \eta_\sigma, \eta_\lambda, \eta_\gamma, \eta_\alpha$  as presented in Koehler, Umlauf, and Greven (2016), see also [jm\\_bamlss](#). Survival times are sampled using the inversion method (cf. Bender, Augustin, & Blettner, 2005). Additional censoring and missingness is introduced. The longitudinal information is censored according to the survival information. The user can also specify own predictors and use only rJM to simulate survival times accordingly.

Pre-specified functions for  $\eta_\mu$  in `long_setting` are for linear

$$\eta_{\mu i}(t) = 1.25 + r_{1i} + 0.6 \sin(x_{2i}) + (-0.01)t + 0.02r_{2i}t$$

, for nonlinear

$$\eta_{\mu i}(t) = 0.5 + r_{1i} + 0.6 \sin(x_{2i}) + 0.1(t + 1) \exp(-0.075t)$$

and for functional

$$\eta_{\mu i}(t) = 0.5 + r_{1i} + 0.6 \sin(x_{2i}) + 0.1(t + 1) \exp(-0.075t) + \sum_k \beta_{ki} B(t)$$

, where  $B(\cdot)$  denotes a B-spline basis function and  $\beta_{ki}$  are the sampled penalized coefficients from `gen_b` per person.

Prespecified functions for  $\eta_\alpha$  in `alpha_setting` are for constant

$$\eta_\alpha(t) = 1$$

, for linear

$$\eta_\alpha(t) = 1 - 0.015t$$

, for nonlinear

$$\eta_\alpha(t) = \cos((time - 20)/20)$$

, and for nonlinear

$$\eta_\alpha(t) = \cos((time - 33)/33)$$

.

Additionally the fixed functions for  $\eta_\lambda = 0.1(t+2) \exp(-0.075t)$  and  $\eta_\lambda = 0.1(t+2) \exp(-0.075t)$  are employed.

**Value**

For `full = TRUE` a list of the three data.frames is returned:

|                        |                                                                                                                           |
|------------------------|---------------------------------------------------------------------------------------------------------------------------|
| <code>data</code>      | Simulated dataset in long format including all longitudinal and survival covariates.                                      |
| <code>data_grid</code> | Dataset of the time-varying survival predictors which are not subject specific, evaluated at a grid of fixed time points. |
| <code>data_full</code> | Simulated data set prior to generating longitudinal missings. Useful to assess the longitudinal fit.                      |

For `full = FALSE` only the first dataset is returned.

Covariates within these datasets include a subject identifier `id`, the sampled survival times `survtime`, the event indicator `event`, the time points of longitudinally "observed" measurements `obstime`, the longitudinal response `y`, the cumulative hazard at the survival time `cumhaz`, as well as covariates `x1`, `x2`, random effects `r1`, `r2`, `b1`, . . . , and the true predictors `alpha`, `lambda`, `gamma`, `mu`, `sigma`.

**References**

Hofner, B (2016). **CoxFlexBoost**: Boosting Flexible Cox Models (with Time-Varying Effects). R package version 0.7-0.

Bender, R., Augustin, T., and Blettner, M. (2005). Generating Survival Times to Simulate Cox Proportional Hazards Models. *Statistics in Medicine*, **24**, 1713-1723.

Koehler N, Umlauf N, Beyerlein, A., Winkler, C., Ziegler, A., and Greven S (2016). Flexible Bayesian Additive Joint Models with an Application to Type 1 Diabetes Research. (*submitted*)

**See Also**

[jm\\_bamlss](#), [opt\\_JM](#), [sam\\_JM](#), [bamlss](#).

**Examples**

```
## Not run: ## Simulate survival data
## with functional random intercepts and a nonlinear effect
## of time, time-varying association alpha.
d <- simJM(nsub = 300)
head(d)

## Simulate survival data
## with random intercepts/slopes and a linear effect of time,
## constant association alpha.
d <- simJM(nsub = 200, long_setting = "linear",
  alpha_setting = "constant")
head(d)

## End(Not run)
```

## Description

Function `simSurv()` and `rSurvtime2()` simulate arbitrary (Cox-type) survival times using the inversion method. Function `simSurv()` is a simple wrapper that calls `rSurvtime2()`. The functions are based on the R package **CoxFlexBoost** implementation `rSurvtime()` and only slightly modify the code.

## Usage

```
## Simulate a pre-specified survival times data set.
simSurv(n = 300)

## Simulate arbitrary survival times.
rSurvTime2(lambda, x, cens_fct, upper = 1000, ...,
  file = NULL, subdivisions = 1000)
```

## Arguments

|                           |                                                                                                                                                                  |
|---------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>n</code>            | The number of individuals for which survival times should be simulated.                                                                                          |
| <code>lambda</code>       | function. Baseline hazard $\lambda(t, x)$ where time must be first argument.                                                                                     |
| <code>x</code>            | matrix. (Sampled) values for covariates (without time).                                                                                                          |
| <code>cens_fct</code>     | function. Function to compute (random) censoring.                                                                                                                |
| <code>upper</code>        | upper boundary of the interval the random survival times fall into.                                                                                              |
| <code>...</code>          | further arguments to be passed to <code>lambda</code> or <code>cens_fct</code> .                                                                                 |
| <code>file</code>         | character. name of the data file the generated data set should be stored into (e.g., "survtimes.RData") or NULL if the dataset should directly be returned in R. |
| <code>subdivisions</code> | The maximum number of subintervals for the integration.                                                                                                          |

## Details

This is basically a slight modification according the computation of the integral, see the manual page of function `rSurvtime()` of package **CoxFlexBoost** for details.

## Value

A data.frame consisting of the observed survival time (`time`), the non-censoring indicator (`event`) and further covariates `x` is returned. If `file` is specified, the data.frame is additionally stored on the disc.

## References

Benjamin Hofner (2016). **CoxFlexBoost**: Boosting Flexible Cox Models (with Time-Varying Effects). R package version 0.7-0.

Ralph Bender and Thomas Augustin and Maria Blettner (2005), Generating Survival Times to Simulate Cox Proportional Hazards Models. *Statistics in Medicine*, **24**, 1713-1723.

## See Also

[cox\\_bamlss](#), [opt\\_Cox](#), [sam\\_Cox](#), [bamlss](#)

## Examples

```
## The following shows the code of the
## wrapper function simSurv().
set.seed(111)
n <- 100
X <- matrix(NA, nrow = n, ncol = 3)
X[, 1] <- runif(n, -1, 1)
X[, 2] <- runif(n, -3, 3)
X[, 3] <- runif(n, -1, 1)

## Specify censoring function.
cens_fct <- function(time, mean_cens) {
  ## Censoring times are independent exponentially distributed.
  censor_time <- rexp(n = length(time), rate = 1 / mean_cens)
  event <- (time <= censor_time)
  t_obs <- apply(cbind(time, censor_time), 1, min)
  ## Return matrix of observed survival times and event indicator.
  return(cbind(t_obs, event))
}

## log(time) is the baseline hazard.
lambda <- function(time, x) {
  exp(log(time) + 0.7 * x[1] + sin(x[2]) + sin(time * 2) * x[3])
}

## Simulate data with lambda() and cens_fct().
d <- rSurvTime2(lambda, X, cens_fct, mean_cens = 5)
```

---

sliceplot

*Plot Slices of Bivariate Functions*

---

## Description

This function plots slices from user defined values of bivariate surfaces.

**Usage**

```
sliceplot(x, y = NULL, z = NULL, view = 1, c.select = NULL,
  values = NULL, probs = c(0.1, 0.5, 0.9), grid = 100,
  legend = TRUE, pos = "topright", digits = 2, data = NULL,
  rawdata = FALSE, type = "mba", linear = FALSE,
  extrap = FALSE, k = 40, rug = TRUE, rug.col = NULL,
  jitter = TRUE, ...)
```

**Arguments**

|          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| x        | A matrix or data frame, containing the covariates for which the effect should be plotted in the first and second column and at least a third column containing the effect. Another possibility is to specify the plot via a formula, e.g., for simple plotting of bivariate surfaces $z \sim x + y$ , see the examples.                                                                                                                                                                |
| y        | If x is a vector the argument y and z must also be supplied as vectors.                                                                                                                                                                                                                                                                                                                                                                                                                |
| z        | If x is a vector the argument y and z must also be supplied as vectors, z defines the surface given by $z = f(x, y)$ .                                                                                                                                                                                                                                                                                                                                                                 |
| view     | Which variable should be used for the x-axis of the plot, the other variable will be used to compute the slices. May also be a character with the name of the corresponding variable.                                                                                                                                                                                                                                                                                                  |
| c.select | Integer, selects the column that is used in the resulting matrix to be used as the z argument.                                                                                                                                                                                                                                                                                                                                                                                         |
| values   | The values of the x or y variable that should be used for computing the slices, if set to NULL, slices will be constructed according to the quantiles, see also argument probs.                                                                                                                                                                                                                                                                                                        |
| probs    | Numeric vector of probabilities with values in [0,1] to be used within function <a href="#">quantile</a> to compute the values for plotting the slices.                                                                                                                                                                                                                                                                                                                                |
| grid     | The grid size of the surface where the slices are generated from.                                                                                                                                                                                                                                                                                                                                                                                                                      |
| legend   | If set to TRUE, a legend with the values that where used for slicing will be added.                                                                                                                                                                                                                                                                                                                                                                                                    |
| pos      | The position of the legend, see also function <a href="#">legend</a> .                                                                                                                                                                                                                                                                                                                                                                                                                 |
| digits   | The decimal place the legend values should be rounded.                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| data     | If x is a formula, a data.frame or list. By default the variables are taken from <code>environment(x)</code> : typically the environment from which <code>plot3d</code> is called.                                                                                                                                                                                                                                                                                                     |
| rawdata  | If set to TRUE, the data will not be interpolated, only raw data will be used. This is useful when displaying data on a regular grid.                                                                                                                                                                                                                                                                                                                                                  |
| type     | Character, which type of interpolation method should be used. The default is <code>type = "akima"</code> , see function <a href="#">interp</a> . The two other options are <code>type = "mba"</code> , which calls function <code>mba.surf</code> of package <b>MBA</b> , or <code>type = "mgcv"</code> , which uses a spatial smoother withing package <b>mgcv</b> for interpolation. The last option is definitely the slowest, since a full regression model needs to be estimated. |
| linear   | Logical, should linear interpolation be used withing function <a href="#">interp</a> ?                                                                                                                                                                                                                                                                                                                                                                                                 |
| extrap   | Logical, should interpolations be computed outside the observation area (i.e., extrapolated)?                                                                                                                                                                                                                                                                                                                                                                                          |

|         |                                                                                                                         |
|---------|-------------------------------------------------------------------------------------------------------------------------|
| k       | Integer, the number of basis functions to be used to compute the interpolated surface when <code>type = "mgcv"</code> . |
| rug     | Add a <a href="#">rug</a> to the plot.                                                                                  |
| jitter  | If set to TRUE a <a href="#">jittered rug</a> plot is added.                                                            |
| rug.col | Specify the color of the rug representation.                                                                            |
| ...     | Parameters passed to <a href="#">matplot</a> and <a href="#">legend</a> .                                               |

### Details

Similar to function [plot3d](#), this function first applies bivariate interpolation on a regular grid, afterwards the slices are computed from the resulting surface.

### Note

Function `sliceplot` can use the **akima** package to construct smooth interpolated surfaces, therefore, package **akima** needs to be installed. The **akima** package has an ACM license that restricts applications to non-commercial usage, see

<https://www.acm.org/publications/policies/software-copyright-notice>

Function `sliceplot` prints a note referring to the ACM license. This note can be suppressed by setting

```
options("use.akima" = TRUE)
```

### See Also

[plot2d](#), [plot3d](#), [plotmap](#), [plotblock](#).

### Examples

```
## Generate some data.
set.seed(111)
n <- 500

## Regressors.
d <- data.frame(z = runif(n, -3, 3), w = runif(n, 0, 6))

## Response.
d$y <- with(d, 1.5 + cos(z) * sin(w) + rnorm(n, sd = 0.6))

## Not run: ## Estimate model.
b <- bamlss(y ~ te(z, w), data = d)
summary(b)

## Plot estimated effect.
plot(b, term = "te(z,w)", sliceplot = TRUE)
plot(b, term = "te(z,w)", sliceplot = TRUE, view = 2)
plot(b, term = "te(z,w)", sliceplot = TRUE, view = "w")
plot(b, term = "te(z,w)", sliceplot = TRUE, probs = seq(0, 1, length = 10))

## End(Not run)
```



```
## Variations.
d$f1 <- with(d, sin(z) * cos(w))
sliceplot(cbind(z = d$z, w = d$w, f1 = d$f1))

## Same with formula.
sliceplot(sin(z) * cos(w) ~ z + w, ylab = "f(z)", data = d)

## Compare with plot3d().
plot3d(sin(z) * 1.5 * w ~ z + w, zlab = "f(z,w)", data = d)
sliceplot(sin(z) * 1.5 * w ~ z + w, ylab = "f(z)", data = d)
sliceplot(sin(z) * 1.5 * w ~ z + w, view = 2, ylab = "f(z)", data = d)
```

---

smooth.construct

*Constructor Functions for Smooth Terms in BAMLSS*


---

## Description

The generic function is only a copy of `smooth.construct` adding a `...` argument. For objects of class `"bamlss.frame"` and `"bamlss"` the method extracts all smooth model terms, see function `bamlss.frame` for details on the setup of BAMLSS.

## Usage

```
## Function as in package mgcv
## but with additional dots argument.
smooth.construct(object, data, knots, ...)

## For 'bamlss.frame's.
## S3 method for class 'bamlss.frame'
smooth.construct(object, data = NULL, knots = NULL,
  model = NULL, drop = TRUE, ...)

## S3 method for class 'bamlss.formula'
smooth.construct(object, data = NULL, knots = NULL,
  model = NULL, drop = TRUE, ...)

## S3 method for class 'bamlss.terms'
smooth.construct(object, data = NULL, knots = NULL,
  model = NULL, drop = TRUE, ...)
```

## Arguments

|                     |                                                                                                                                                                                                                                                              |
|---------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>object</code> | Either a smooth specification object, or object of class <code>"bamlss"</code> , <code>"bamlss.frame"</code> , <code>"bamlss.formula"</code> or <code>"bamlss.terms"</code> . For smooth specification objects, see function <code>smooth.construct</code> . |
| <code>data</code>   | A data frame or list, see also see function <code>smooth.construct</code> .                                                                                                                                                                                  |
| <code>knots</code>  | See function <code>smooth.construct</code> .                                                                                                                                                                                                                 |

|       |                                                                                         |
|-------|-----------------------------------------------------------------------------------------|
| model | Character, specifies for which model parameter the smooth constructs should be created. |
| drop  | If there is only one model parameter the returned named list is simplified.             |
| ...   | Arguments passed to the smooth term constructor functions.                              |

**Value**

For smooth specification objects see function see [smooth.construct](#). For objects of class "bamlss.frame" or "bamlss" the list of smooth constructs, see function [bamlss.frame](#) for more details.

**See Also**

[bamlss.frame](#), [bamlss.formula](#), [bamlss](#), [smooth.construct](#).

**Examples**

```
## Generate some data.
d <- GAMart()

## Create a "bamlss.frame".
bf <- bamlss.frame(num ~ s(x1) + s(x2), data = d)

## Extract the smooth construct.
sc <- smooth.construct(bf)
str(sc)

## Also possible with formulas.
f <- bamlss.formula(list(
  num ~ s(x1) + te(lon,lat),
  sigma ~ s(x2)
), family = "gaussian")

sc <- smooth.construct(f, data = d)
str(sc)
```

---

smooth.construct.kr.smooth.spec  
*Kriging Smooth Constructor*

---

**Description**

This smooth constructor implements a kriging based model term.

**Usage**

```
## S3 method for class 'kr.smooth.spec'
smooth.construct(object, data, knots, ...)
## S3 method for class 'kriging.smooth'
Predict.matrix(object, data)
```

## Arguments

object, data, knots  
See [smooth.construct](#).  
... Currently not used.

## Details

This smooth constructor implements univariate and bivariate Kriging terms. The basis functions are based on the [matern](#) function. For finding knots, a space filling algorithm is used, see [cover.design](#).

## Value

A smooth specification object, see also [smooth.construct](#).

## References

Fahrmeir, L., Kneib, T., Lang, S., Marx, B. (2013): Regression. Models, Methods and Applications, Springer Verlag. <https://www.uni-goettingen.de/de/551357.html>

## See Also

[bamlss](#), [smooth.construct](#)

## Examples

```
## Not run: ## Simulate data.
set.seed(123)
d <- GAMart()

## Estimate model.
f <- num ~ s(x1,bs="kr") + s(x2,bs="kr") + s(x3,bs="kr") + s(lon,lat,bs="kr",k=30)

## Set the seed, estimate model.
set.seed(111)
b <- bamlss(f, data = d)

## Plot estimated effects.
plot(b)

## End(Not run)
```

---

smooth.construct.ms.smooth.spec

*Smooth constructor for monotonic P-splines*

---

## Description

The function sets up a smooth term for shape constraint estimation of P-spline model terms. Note that this currently only works using boosting and backfitting.

**Usage**

```
## S3 method for class 'ms.smooth.spec'
smooth.construct(object, data, knots, ...)
```

**Arguments**

|        |                                                                                                                                                                                                          |
|--------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| object | Either a smooth specification object, or object of class "bamlss", "bamlss.frame", "bamlss.formula" or "bamlss.terms". For smooth specification objects, see function <a href="#">smooth.construct</a> . |
| data   | A data frame or list, see also see function <a href="#">smooth.construct</a> .                                                                                                                           |
| knots  | See function <a href="#">smooth.construct</a> .                                                                                                                                                          |
| ...    | Arguments passed to the smooth term constructor functions.                                                                                                                                               |

**Value**

See function see [smooth.construct](#).

**See Also**

[bamlss.frame](#), [bamlss.formula](#), [bamlss](#), [smooth.construct](#).

**Examples**

```
## Not run: ## Generate some data.
set.seed(123)

n <- 300
x <- runif(n, -2, 3)
y <- sin(x) + rnorm(n, sd = 0.1)

## Increasing: constr = 1.
## Decreasing: constr = 2.
b <- bamlss(y ~ s2(x,bs="ms",xt=list(constr=1)),
  data = d, sampler = FALSE, optimizer = opt_bfit)

## Predict and plot.
p <- predict(b, model = "mu")
plot(y ~ x)
plot2d(p ~ x, add = TRUE, col.lines = 4, lwd = 2)

## End(Not run)
```

---

```
smooth.construct.sr.smooth.spec
```

*Random Effects P-Spline*

---

## Description

This smooth constructor implements the random effects representation of a P-spline.

## Usage

```
## S3 method for class 'sr.smooth.spec'  
smooth.construct(object, data, knots, ...)
```

## Arguments

```
object, data, knots          See smooth.construct.  
...                          Currently not used.
```

## Value

See [smooth.construct](#)

## See Also

[bamfss](#), [predict.bamfss](#), [opt\\_bfit](#), [opt\\_boost](#)

## Examples

```
## Not run: ## Simulate data.  
set.seed(123)  
d <- GAMart()  
  
## Estimate model.  
f <- num ~ x1 + x2 + x3 + s2(x1,bs="sr") + s2(x2,bs="sr") + s2(x3,bs="sr")  
  
b <- bamfss(f, data = d, optimizer = boost, sampler = FALSE)  
  
plot(b)  
  
## End(Not run)
```

smooth\_check

*MCMC Based Simple Significance Check for Smooth Terms***Description**

For each smooth term estimated with MCMC, the function computes 95 intervals and simply computes the fraction of the cases where the interval does not contain zero.

**Usage**

```
smooth_check(object, newdata = NULL, model = NULL, term = NULL, ...)
```

**Arguments**

|         |                                                          |
|---------|----------------------------------------------------------|
| object  | A fitted model object which contains MCMC samples.       |
| newdata | Optionally, use new data for computing the check.        |
| model   | Character, for which model should the check be computed? |
| term    | Character, for which term should the check be computed?  |
| ...     | Arguments passed to <a href="#">predict.bamlss</a> .     |

**Examples**

```
## Not run: ## Simulate some data.
d <- GAMart()

## Model formula.
f <- list(
  num ~ s(x1) + s(x2) + s(x3),
  sigma ~ s(x1) + s(x2) + s(x3)
)

## Estimate model with MCMC.
b <- bamlss(f, data = d)

## Run the check, note that all variables
## for sigma should have no effect.
smooth_check(b)

## End(Not run)
```

---

|         |                             |
|---------|-----------------------------|
| stabsel | <i>Stability selection.</i> |
|---------|-----------------------------|

---

## Description

Performs stability selection based on gradient boosting.

## Usage

```
stabsel(formula, data, family = "gaussian",
        q, maxit, B = 100, thr = .9, fraction = 0.5, seed = NULL, ...)

## Plot selection frequencies.
## S3 method for class 'stabsel'
plot(x, show = NULL,
     pal = function(n) gray.colors(n, start = 0.9, end = 0.3), ...)
```

## Arguments

|          |                                                                                                                                                                  |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| formula  | A formula or extended formula.                                                                                                                                   |
| data     | A <a href="#">data.frame</a> .                                                                                                                                   |
| family   | A <a href="#">bamlss.family</a> object.                                                                                                                          |
| q        | An integer specifying how many terms to select in each boosting run.                                                                                             |
| maxit    | An integer specifying the maximum number of boosting iterations. See <a href="#">opt_boost</a> . Either choose q or maxit as hyper-parameter for regularization. |
| B        | An integer. The boosting is run B times.                                                                                                                         |
| thr      | Cut-off threshold of relative frequencies (between 0 and 1) for selection.                                                                                       |
| fraction | Numeric between 0 and 1. The fraction of data to be used in each boosting run.                                                                                   |
| seed     | A seed to be set before the stability selection.                                                                                                                 |
| x        | A object of class stabsel.                                                                                                                                       |
| show     | Number of terms to be shown.                                                                                                                                     |
| pal      | Color palette for different model terms.                                                                                                                         |
| ...      | Not used yet in stabsel.                                                                                                                                         |

## Details

stabsel performs stability selection based on gradient boosting ([opt\\_boost](#)): The boosting algorithm is run B times on a randomly drawn fraction of the data. Each boosting run is stopped either when q terms have been selected, or when maxit iterations have been performed, i.e. either q or maxit can be used to tune the regularization of the boosting. After the boosting the relative selection frequencies are evaluated. Terms with a relative selection frequency larger than thr are suggested for a final regression model.

If neither `q` nor `maxit` has been specified, `q` will be set to the square root of the number of columns in data.

Gradient boosting does not depend on random numbers. Thus, the individual boosting runs differ only in the subset of data which is used.

### Value

A object of class `stabsel`.

### Author(s)

Thorsten Simon

### Examples

```
## Not run: ## Simulate some data.
set.seed(111)
d <- GAMart()
n <- nrow(d)

## Add some noise variables.
for(i in 4:9)
  d[[paste0("x",i)]] <- rnorm(n)

f <- paste0("~ ", paste("s(x", 1:9, ")", collapse = "+", sep = ""))
f <- paste(f, "+ te(lon,lat)")
f <- as.formula(f)
f <- list(update(f, num ~ .), f)

## Run stability selection.
sel <- stabsel(f, data = d, q = 6, B = 10)
plot(sel)

## Estimate selected model.
nf <- formula(sel)
b <- bamlss(nf, data = d)
plot(b)

## End(Not run)
```

---

summary.bamlss

*Summary for BAMLSS*

---

### Description

The function takes an object of class `"bamlss"` and produces summaries of optimizer and sampler function outputs.



**Usage**

```
## S3 method for class 'bamlss'
summary(object, model = NULL,
        FUN = NULL, parameters = TRUE, ...)

## S3 method for class 'summary.bamlss'
print(x, digits = max(3, getOption("digits") - 3), ...)
```

**Arguments**

|            |                                                                                                                                                   |
|------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| object     | An object of class "bamlss".                                                                                                                      |
| x          | An object of class "summary.bamlss".                                                                                                              |
| model      | Character or integer, specifies the model for which a summary should be computed.                                                                 |
| FUN        | Function that should be applied on samples, see also function <a href="#">coef.bamlss</a> .                                                       |
| parameters | If an optimizer function is applied within the <a href="#">bamlss</a> call, should the values of the estimated parameters be part of the summary? |
| digits     | Controls number of digits printed in output.                                                                                                      |
| ...        | Other arguments.                                                                                                                                  |

**Details**

If the fitted model contains samples, summaries according to the supplied function can be computed, e.g., different quantiles of samples. See also function [coef.bamlss](#) that extracts the coefficient summaries.

If an optimizer function was used within the [bamlss](#) call, estimated parameters will be included per default into the summary.

Note that summaries not based on samples can be user defined, e.g., as returned from function [samplestats](#) or the return values of optimizer function, e.g., see function [opt\\_bfit](#).

**Value**

summary.bamlss produces the following summary:

|                  |                                                                                                                              |
|------------------|------------------------------------------------------------------------------------------------------------------------------|
| call             | The initial <a href="#">bamlss</a> call.                                                                                     |
| family           | The family that is used for modeling.                                                                                        |
| formula          | The model formula.                                                                                                           |
| model.matrix     | Summary of parameteric terms.                                                                                                |
| smooth.construct | Summary of smooth terms.                                                                                                     |
| model.stats      | Other model statistics, e.g., as returned from optimizer functions and/or produces by function <a href="#">samplestats</a> . |

**See Also**

[bamlss](#)

**Examples**

```
## Not run: ## Generate some data.
d <- GAMart()

## Model formula.
f <- list(
  num ~ s(x1) + s(x2),
  sigma ~ s(x3) + te(lon,lat)
)

## Estimate model.
b <- bamlss(f, data = d)

## Print the summary.
print(summary(b))

## End(Not run)
```

---

Surv2

*Create a Survival Object for Joint Models*

---

**Description**

This function is only a slight extension of [Surv](#) for joint models.

**Usage**

```
Surv2(..., obs = NULL)
```

**Arguments**

|     |                                                     |
|-----|-----------------------------------------------------|
| ... | Arguments passed to function <a href="#">Surv</a> . |
| obs | The observed longitudinal response.                 |

**Value**

An object of class "Surv2" and "matrix".

**See Also**

[opt\\_JM](#), [sam\\_JM](#), [bamlss](#)

**Examples**

```
## Surv2(time, event, obs = y)
## See the examples of opt_JM() and sam_JM()!
```

---

|                |                                            |
|----------------|--------------------------------------------|
| surv_transform | <i>Survival Model Transformer Function</i> |
|----------------|--------------------------------------------|

---

### Description

This function takes a `bamlss.frame` and computes design matrices of model terms based on a time grid for time-dependent structured additive predictors in a survival context. Note that this transformer function is usually used internally by function `bamlss` and is the default transformer function using the `cox_bamlss` family object.

The time grid design matrices can be used to construct the full structured additive predictor for each time point. This way it is possible to solve the integrals that are part of, e.g., a Newton-Raphson updating scheme, numerically.

See the example section on how to extract the time grid design matrices.

### Usage

```
surv_transform(x, y, data, family,
  subdivisions = 100, timedependent = "lambda",
  timevar = NULL, idvar = NULL, is.cox = FALSE,
  alpha = 0.1, ...)
```

### Arguments

|               |                                                                                                                                                                                                                |
|---------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| x             | The x list, as returned from function <code>bamlss.frame</code> and transformed by function <code>surv_transform</code> , holding all model matrices and other information that is used for fitting the model. |
| y             | The model response, as returned from function <code>bamlss.frame</code> .                                                                                                                                      |
| data          | The data.frame that should be used for setting up all matrices.                                                                                                                                                |
| family        | A <b>bamlss</b> family object, see <code>family.bamlss</code> . In this case this is the <code>cox_bamlss</code> family object.                                                                                |
| subdivisions  | How many time points should be created for each individual.                                                                                                                                                    |
| timedependent | A character vector specifying the names of parameters in x that are time-dependent. Time grid design matrices are only computed for these parameters.                                                          |
| timevar       | A character specifying the name of the survival time variable in the data set.                                                                                                                                 |
| idvar         | Depending on the type of data set, this is the name of the variable specifying identifier of individuals.                                                                                                      |
| is.cox        | Should the <code>bamlss.frame</code> be set up for a Cox type survival model.                                                                                                                                  |
| alpha         | A value for the intercept of a parameter names alpha. Typically the association parameter of a longitudinal and survival process in a joint model.                                                             |
| ...           | Arguments passed to function <code>bamlss.engine.setup</code> .                                                                                                                                                |

### Value

A `bamlss.frame` including the time grid design matrices.

**See Also**

[cox\\_bamlss](#), [opt\\_Cox](#), [sam\\_Cox](#), [simSurv](#), [bamlss](#)

**Examples**

```

library("survival")
set.seed(111)

## Simulate survival data.
d <- simSurv(n = 20)

## Formula of the survival model, note
## that the baseline is given in the first formula by s(time).
f <- list(
  Surv(time, event) ~ s(time) + s(time, by = x3),
  gamma ~ s(x1) + s(x2)
)

## Create the bamlss.frame.
bf <- bamlss.frame(f, family = "cox", data = d)

## Lambda is the time-dependent parameter.
print(bf)

## Apply the transformer.
bf <- with(bf, surv_transform(x, y, data = model.frame,
  family = family, is.cox = TRUE, subdivisions = 25))

## Extract the time grid design matrix for term s(time).
X <- bf$x$lambda$smooth.construct[["s(time)"]][fit.fun_timegrid(NULL)
dim(X)

## Compute fitted values for each time point.
grid <- attr(bf$y[[1]], "grid")
gdim <- c(length(grid), length(grid[[1]]))
b <- runif(ncol(X))
fit <- X %*% b
fit <- matrix(fit, nrow = gdim[1], ncol = gdim[2], byrow = TRUE)

plot(as.vector(fit) ~ unlist(grid), type = "n",
  xlab = "Survival time", ylab = "Effect")
for(j in seq_along(grid)) {
  lines(fit[j, ] ~ grid[[j]], lwd = 2, col = rgb(0.1, 0.1, 0.1, alpha = 0.3))
  points(grid[[j]][gdim[2]], fit[j, gdim[2]], col = "red")
}

```

**Description**

Extract `terms.objects` for BAMLSS.

**Usage**

```
## S3 method for class 'bamlss'
terms(x, specials = NULL, data = NULL,
      model = NULL, pterms = TRUE, sterms = TRUE,
      drop = TRUE, ...)

## S3 method for class 'bamlss.frame'
terms(x, specials = NULL, data = NULL,
      model = NULL, pterms = TRUE, sterms = TRUE,
      drop = TRUE, ...)

## S3 method for class 'bamlss.formula'
terms(x, specials = NULL, data = NULL,
      model = NULL, pterms = TRUE, sterms = TRUE,
      drop = TRUE, ...)
```

**Arguments**

|                       |                                                                                                  |
|-----------------------|--------------------------------------------------------------------------------------------------|
| <code>x</code>        | An link{ <code>bamlss</code> }, <code>bamlss.frame</code> or <code>bamlss.formula</code> object. |
| <code>specials</code> | See <code>terms.object</code> .                                                                  |
| <code>data</code>     | Data passed to <code>terms.formula</code> .                                                      |
| <code>model</code>    | Character or integer, specifies the model for which terms should be returned.                    |
| <code>pterms</code>   | Should parametric terms be part of the object?                                                   |
| <code>sterms</code>   | Should smooth terms be part of the object?                                                       |
| <code>drop</code>     | If terms for only one model are returned, the list structure is dropped.                         |
| <code>...</code>      | Arguments passed to <code>bamlss.formula</code> .                                                |

**Value**

Object of class "bamlss.terms", a list of `terms.objects`, depending on the structure of the `bamlss.formula` object.

**See Also**

`bamlss`, `bamlss.frame`, `bamlss.formula`.

**Examples**

```
## Model formula.
f <- list(
  num ~ x1 + x2 + id,
  sigma ~ x3 + fac + lon + lat
)
```

```
## Create the terms object.  
terms(bamlss.formula(f))
```

---

|           |                                 |
|-----------|---------------------------------|
| trans_AR1 | <i>AR1 Transformer Function</i> |
|-----------|---------------------------------|

---

### Description

The transformer function takes a [bamlss.frame](#) object and transforms the response and the design matrices to account for lag 1 autocorrelation. The method is also known as Prais-Winsten estimation.

### Usage

```
trans_AR1(rho = 0.1)  
AR1(rho = 0.1)
```

### Arguments

rho                      Specifies the correlation parameter at lag 1.

### Value

A transformer function which can be used in the [bamlss](#) call.

### References

Johnston, John (1972). *Econometric Methods* (2nd ed.). New York: McGraw-Hill. pp. 259–265.

### See Also

[bamlss.frame](#), [bamlss](#), [smooth2random](#).

### Examples

```
## Not run: ## Simulate AR1 data.  
set.seed(111)  
  
n <- 240  
d <- data.frame("t" = 1:n)  
  
## Nonlinear function.  
f <- function(x) {  
  2 + sin(x / n * 2 * pi - pi)  
}  
  
## Correlated errors.  
rho <- 0.8
```

```

e <- rnorm(n, sd = 0.1)
u <- c(e[1], rep(NA, n - 1))
for(i in 2:n){
  u[i] <- rho * u[i - 1] + e[i]
}

## Response.
d$y <- f(d$t) + u

## Plot time-series data.
plot(d, type = "l")

## Estimate models without and with AR1 transformation.
b0 <- bamlss(y ~ s(t,k=20), data = d, criterion = "BIC")
b1 <- bamlss(y ~ s(t,k=20), data = d, criterion = "BIC",
  transform = AR1(rho = 0.8))

## Estimate full AR1 model.
b2 <- bamlss(y ~ s(t,k=20), data = d, criterion = "BIC",
  family = "AR1")
rho <- predict(b2, model = "rho", type = "parameter")
print(range(rho))

## Estimated standard deviations.
sd0 <- predict(b0, model = "sigma", type = "parameter")
sd1 <- predict(b1, model = "sigma", type = "parameter")
sd2 <- predict(b2, model = "sigma", type = "parameter")
print(round(c(sd0[1], sd1[1], sd2[1]), 2))

## Plot fitted trends.
p0 <- predict(b0, model = "mu")
p1 <- predict(b1, model = "mu")
p2 <- predict(b2, model = "mu")

plot(d, type = "l")
lines(f(d$t) ~ d$t, col = 2, lwd = 2)
lines(p0 ~ d$t, col = 4, lwd = 2)
lines(p1 ~ d$t, col = 3, lwd = 3)
lines(p2 ~ d$t, col = 5, lwd = 3)
legend("topleft",
  c("no trans", "with trans", "AR1 model", "truth"),
  lwd = 2, col = c(4, 3, 5, 2), bty = "n")

## End(Not run)

```

**Description**

This function creates a data set based on the [volcano](#) data by adding normal errors to the topographic information.

**Usage**

```
Volcano(sd = 0.3)
```

**Arguments**

`sd`                    The standard deviation of the normal errors.

**Value**

A data frame with coordinates and noisy elevation.

**See Also**

[volcano](#)

**Examples**

```
d <- Volcano()
head(d)

## Not run: b <- bamlss(y ~ te(lon,lat,k=10), data = d)
plot(b, theta = -130)

## End(Not run)
```

---

WAIC

*Watanabe-Akaike Information Criterion (WAIC)*

---

**Description**

Function returning the Watanabe-Akaike Information Criterion (WAIC) of a fitted model object.

**Usage**

```
WAIC(object, ..., newdata = NULL)
```

**Arguments**

`object`                A fitted model object which contains MCMC samples.  
`...`                    Optionally more fitted model objects.  
`newdata`                Optionally, use new data for computing the WAIC.



**Value**

A data frame containing the WAIC and estimated number of parameters.

**References**

Watanabe S. (2010). Asymptotic Equivalence of Bayes Cross Validation and Widely Applicable Information Criterion in Singular Learning Theory. *The Journal of Machine Learning Research*, **11**, 3571–3594. <https://jmlr.org/papers/v11/watanabe10a.html>

**Examples**

```
## Not run: d <- GAMart()
b1 <- bamlss(num ~ s(x1), data = d)
b2 <- bamlss(num ~ s(x1) + s(x2), data = d)
WAIC(b1, b2)

## End(Not run)
```

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