

Package ‘rstanarm’

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Type Package

Title Bayesian Applied Regression Modeling via Stan

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Description Estimates previously compiled regression models using the 'rstan' package, which provides the R interface to the Stan C++ library for Bayesian estimation. Users specify models via the customary R syntax with a formula and data.frame plus some additional arguments for priors.

License GPL (>= 3)

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rstanarm-package

*Applied Regression Modeling via RStan***Description**

The **rstanarm** package is an appendage to the **rstan** package that enables many of the most common applied regression models to be estimated using Markov Chain Monte Carlo, variational approximations to the posterior distribution, or optimization. The **rstanarm** package allows these models to be specified using the customary R modeling syntax (e.g., like that of `glm` with a formula and a `data.frame`).

The sections below provide an overview of the modeling functions and estimation algorithms used by **rstanarm**.

Details

The set of models supported by **rstanarm** is large (and will continue to grow), but also limited enough so that it is possible to integrate them tightly with the `pp_check` function for graphical posterior predictive checks with `bayesplot` and the `posterior_predict` function to easily estimate the effect of specific manipulations of predictor variables or to predict the outcome in a training set.

The objects returned by the **rstanarm** modeling functions are called `stanreg` objects. In addition to all of the typical `methods` defined for fitted model objects, `stanreg` objects can be passed to the

`loo` function in the `loo` package for model comparison or to the `launch_shinystan` function in the `shinystan` package in order to visualize the posterior distribution using the ShinyStan graphical user interface. See the `rstanarm` vignettes for more details about the entire process.

Prior distributions

See [priors help page](#) and the vignette *Prior Distributions for rstanarm Models* for an overview of the various choices the user can make for prior distributions. The package vignettes for the modeling functions also provide examples of using many of the available priors as well as more detailed descriptions of some of the novel priors used by `rstanarm`.

Modeling functions

The model estimating functions are described in greater detail in their individual help pages and vignettes. Here we provide a very brief overview:

`stan_lm`, `stan_aov`, `stan_biglm` Similar to `lm` or `aov` but with novel regularizing priors on the model parameters that are driven by prior beliefs about R^2 , the proportion of variance in the outcome attributable to the predictors in a linear model.

`stan_glm`, `stan_glm.nb` Similar to `glm` but with various possible prior distributions for the coefficients and, if applicable, a prior distribution for any auxiliary parameter in a Generalized Linear Model (GLM) that is characterized by a `family` object (e.g. the shape parameter in Gamma models). It is also possible to estimate a negative binomial model in a similar way to the `glm.nb` function in the `MASS` package.

`stan_glmer`, `stan_glmer.nb`, `stan_lmer` Similar to the `glmer`, `glmer.nb` and `lmer` functions in the `lme4` package in that GLMs are augmented to have group-specific terms that deviate from the common coefficients according to a mean-zero multivariate normal distribution with a highly-structured but unknown covariance matrix (for which `rstanarm` introduces an innovative prior distribution). MCMC provides more appropriate estimates of uncertainty for models that consist of a mix of common and group-specific parameters.

`stan_nlmer` Similar to `nlmer` in the `lme4` package for nonlinear "mixed-effects" models, but the group-specific coefficients have flexible priors on their unknown covariance matrices.

`stan_gamm4` Similar to `gamm4` in the `gamm4` package, which augments a GLM (possibly with group-specific terms) with nonlinear smooth functions of the predictors to form a Generalized Additive Mixed Model (GAMM). Rather than calling `glmer` like `gamm4` does, `stan_gamm4` essentially calls `stan_glmer`, which avoids the optimization issues that often crop up with GAMMs and provides better estimates for the uncertainty of the parameter estimates.

`stan_polr` Similar to `polr` in the `MASS` package in that it models an ordinal response, but the Bayesian model also implies a prior distribution on the unknown cutpoints. Can also be used to model binary outcomes, possibly while estimating an unknown exponent governing the probability of success.

`stan_betareg` Similar to `betareg` in that it models an outcome that is a rate (proportion) but, rather than performing maximum likelihood estimation, full Bayesian estimation is performed by default, with customizable prior distributions for all parameters.

`stan_clogit` Similar to `clogit` in that it models a binary outcome where the number of successes and failures is fixed within each stratum by the research design. There are some minor syntactical differences relative to `clogit` that allow `stan_clogit` to accept group-specific terms as in `stan_glmer`.

`stan_mvmer` A multivariate form of `stan_glm`, whereby the user can specify one or more submodels each consisting of a GLM with group-specific terms. If more than one submodel is specified (i.e. there is more than one outcome variable) then a dependence is induced by assuming that the group-specific terms for each grouping factor are correlated across submodels.

`stan_jm` Estimates shared parameter joint models for longitudinal and time-to-event (i.e. survival) data. The joint model can be univariate (i.e. one longitudinal outcome) or multivariate (i.e. more than one longitudinal outcome). A variety of parameterisations are available for linking the longitudinal and event processes (i.e. a variety of association structures).

Estimation algorithms

The modeling functions in the `rstanarm` package take an `algorithm` argument that can be one of the following:

Sampling (`algorithm="sampling"`) Uses Markov Chain Monte Carlo (MCMC) — in particular, Hamiltonian Monte Carlo (HMC) with a tuned but diagonal mass matrix — to draw from the posterior distribution of the parameters. See `sampling (rstan)` for more details. This is the slowest but most reliable of the available estimation algorithms and it is **the default and recommended algorithm for statistical inference**.

Mean-field (`algorithm="meanfield"`) Uses mean-field variational inference to draw from an approximation to the posterior distribution. In particular, this algorithm finds the set of independent normal distributions in the unconstrained space that — when transformed into the constrained space — most closely approximate the posterior distribution. Then it draws repeatedly from these independent normal distributions and transforms them into the constrained space. The entire process is much faster than HMC and yields independent draws but **is not recommended for final statistical inference**. It can be useful to narrow the set of candidate models in large problems, particularly when specifying `QR=TRUE` in `stan_glm`, `stan_glm`, and `stan_gamm4`, but is **only an approximation to the posterior distribution**.

Full-rank (`algorithm="fullrank"`) Uses full-rank variational inference to draw from an approximation to the posterior distribution by finding the multivariate normal distribution in the unconstrained space that — when transformed into the constrained space — most closely approximates the posterior distribution. Then it draws repeatedly from this multivariate normal distribution and transforms the draws into the constrained space. This process is slower than meanfield variational inference but is faster than HMC. Although still an approximation to the posterior distribution and thus **not recommended for final statistical inference**, the approximation is more realistic than that of mean-field variational inference because the parameters are not assumed to be independent in the unconstrained space. Nevertheless, fullrank variational inference is a more difficult optimization problem and the algorithm is more prone to non-convergence or convergence to a local optimum.

Optimizing (`algorithm="optimizing"`) Finds the posterior mode using a C++ implementation of the LBGFS algorithm. See `optimizing` for more details. If there is no prior information, then this is equivalent to maximum likelihood, in which case there is no great reason to use the functions in the `rstanarm` package over the emulated functions in other packages. However, if priors are specified, then the estimates are penalized maximum likelihood estimates, which may have some redeeming value. Currently, optimization is only supported for `stan_glm`.

References

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- Muth, C., Oravecz, Z., and Gabry, J. (2018) User-friendly Bayesian regression modeling: A tutorial with rstanarm and shinystan. *The Quantitative Methods for Psychology*. 14(2), 99–119. <https://www.tqmp.org/RegularArticles/vol14-2/p099/p099.pdf>

See Also

- <http://mc-stan.org/> for more information on the Stan C++ package used by **rstanarm** for model fitting.
- <https://github.com/stan-dev/rstanarm/issues/> to submit a bug report or feature request.
- <http://discourse.mc-stan.org> to ask a question about **rstanarm** on the Stan-users forum.

adapt_delta

Target average acceptance probability

Description

Details about the adapt_delta argument to **rstanarm**'s modeling functions.

Details

For the No-U-Turn Sampler (NUTS), the variant of Hamiltonian Monte Carlo used by **rstanarm**, adapt_delta is the target average proposal acceptance probability for adaptation. adapt_delta is ignored if algorithm is not "sampling".

The default value of adapt_delta is 0.95, except when the prior for the regression coefficients is **R2**, **hs**, or **hs_plus**, in which case the default is 0.99.

In general you should not need to change `adapt_delta` unless you see a warning message about divergent transitions, in which case you can increase `adapt_delta` from the default to a value *closer* to 1 (e.g. from 0.95 to 0.99, or from 0.99 to 0.999, etc). The step size used by the numerical integrator is a function of `adapt_delta` in that increasing `adapt_delta` will result in a smaller step size and fewer divergences. Increasing `adapt_delta` will typically result in a slower sampler, but it will always lead to a more robust sampler.

References

Stan Development Team. (2017). *Stan Modeling Language Users Guide and Reference Manual*. <http://mc-stan.org/documentation/>

as.matrix.stanreg *Extract the posterior sample*

Description

For models fit using MCMC (`algorithm="sampling"`), the posterior sample—the post-warmup draws from the posterior distribution— can be extracted from a fitted model object as a matrix, data frame, or array. The `as.matrix` and `as.data.frame` methods merge all chains together, whereas the `as.array` method keeps the chains separate. For models fit using optimization ("`optimizing`") or variational inference ("`meanfield`" or "`fullrank`"), there is no posterior sample but rather a matrix (or data frame) of 1000 draws from either the asymptotic multivariate Gaussian sampling distribution of the parameters or the variational approximation to the posterior distribution.

Usage

```
## S3 method for class 'stanreg'
as.matrix(x, ..., pars = NULL, regex_pars = NULL)

## S3 method for class 'stanreg'
as.array(x, ..., pars = NULL, regex_pars = NULL)

## S3 method for class 'stanreg'
as.data.frame(x, ..., pars = NULL, regex_pars = NULL)
```

Arguments

<code>x</code>	A fitted model object returned by one of the rstanarm modeling functions. See stanreg-objects .
<code>...</code>	Ignored.
<code>pars</code>	An optional character vector of parameter names.
<code>regex_pars</code>	An optional character vector of regular expressions to use for parameter selection. <code>regex_pars</code> can be used in place of <code>pars</code> or in addition to <code>pars</code> . Currently, all functions that accept a <code>regex_pars</code> argument ignore it for models fit using optimization.

Value

A matrix, data.frame, or array, the dimensions of which depend on `pars` and `regex_pars`, as well as the model and estimation algorithm (see the Description section above).

See Also

[stanreg-methods](#)

Examples

```
if (!exists("example_model")) example(example_model)
# Extract posterior sample after MCMC
draws <- as.matrix(example_model)
print(dim(draws))

# For example, we can see that the median of the draws for the intercept
# is the same as the point estimate rstanarm uses
print(median(draws[, "(Intercept)"]))
print(example_model$coefficients[["(Intercept)"]])

# The as.array method keeps the chains separate
draws_array <- as.array(example_model)
print(dim(draws_array)) # iterations x chains x parameters

# Extract draws from asymptotic Gaussian sampling distribution
# after optimization
fit <- stan_glm(mpg ~ wt, data = mtcars, algorithm = "optimizing")
draws <- as.data.frame(fit)
print(colnames(draws))
print(nrow(draws)) # 1000 draws are taken

# Extract draws from variational approximation to the posterior distribution
fit2 <- update(fit, algorithm = "meanfield")
draws <- as.data.frame(fit2, pars = "wt")
print(colnames(draws))
print(nrow(draws)) # 1000 draws are taken
```

available-algorithms *Estimation algorithms available for **rstanarm** models*

Description

Estimation algorithms available for **rstanarm** models

Estimation algorithms

The modeling functions in the **rstanarm** package take an `algorithm` argument that can be one of the following:

Sampling (`algorithm="sampling"`) Uses Markov Chain Monte Carlo (MCMC) — in particular, Hamiltonian Monte Carlo (HMC) with a tuned but diagonal mass matrix — to draw from the posterior distribution of the parameters. See [sampling \(rstan\)](#) for more details. This is the slowest but most reliable of the available estimation algorithms and it is **the default and recommended algorithm for statistical inference**.

Mean-field (`algorithm="meanfield"`) Uses mean-field variational inference to draw from an approximation to the posterior distribution. In particular, this algorithm finds the set of independent normal distributions in the unconstrained space that — when transformed into the constrained space — most closely approximate the posterior distribution. Then it draws repeatedly from these independent normal distributions and transforms them into the constrained space. The entire process is much faster than HMC and yields independent draws but **is not recommended for final statistical inference**. It can be useful to narrow the set of candidate models in large problems, particularly when specifying `QR=TRUE` in [stan_glm](#), [stan_glmer](#), and [stan_gamm4](#), but is **only an approximation to the posterior distribution**.

Full-rank (`algorithm="fullrank"`) Uses full-rank variational inference to draw from an approximation to the posterior distribution by finding the multivariate normal distribution in the unconstrained space that — when transformed into the constrained space — most closely approximates the posterior distribution. Then it draws repeatedly from this multivariate normal distribution and transforms the draws into the constrained space. This process is slower than meanfield variational inference but is faster than HMC. Although still an approximation to the posterior distribution and thus **not recommended for final statistical inference**, the approximation is more realistic than that of mean-field variational inference because the parameters are not assumed to be independent in the unconstrained space. Nevertheless, fullrank variational inference is a more difficult optimization problem and the algorithm is more prone to non-convergence or convergence to a local optimum.

Optimizing (`algorithm="optimizing"`) Finds the posterior mode using a C++ implementation of the LBGFS algorithm. See [optimizing](#) for more details. If there is no prior information, then this is equivalent to maximum likelihood, in which case there is no great reason to use the functions in the **rstanarm** package over the emulated functions in other packages. However, if priors are specified, then the estimates are penalized maximum likelihood estimates, which may have some redeeming value. Currently, optimization is only supported for [stan_glm](#).

See Also

<http://mc-stan.org/rstanarm/>

Description

Modeling functions available in **rstanarm**

Modeling functions

The model estimating functions are described in greater detail in their individual help pages and vignettes. Here we provide a very brief overview:

`stan_lm`, `stan_aov`, `stan_biglm` Similar to `lm` or `aov` but with novel regularizing priors on the model parameters that are driven by prior beliefs about R^2 , the proportion of variance in the outcome attributable to the predictors in a linear model.

`stan_glm`, `stan_glm.nb` Similar to `glm` but with various possible prior distributions for the coefficients and, if applicable, a prior distribution for any auxiliary parameter in a Generalized Linear Model (GLM) that is characterized by a `family` object (e.g. the shape parameter in Gamma models). It is also possible to estimate a negative binomial model in a similar way to the `glm.nb` function in the **MASS** package.

`stan_glmer`, `stan_glmer.nb`, `stan_lmer` Similar to the `glmer`, `glmer.nb` and `lmer` functions in the **lme4** package in that GLMs are augmented to have group-specific terms that deviate from the common coefficients according to a mean-zero multivariate normal distribution with a highly-structured but unknown covariance matrix (for which **rstanarm** introduces an innovative prior distribution). MCMC provides more appropriate estimates of uncertainty for models that consist of a mix of common and group-specific parameters.

`stan_nlmer` Similar to `nlmer` in the **lme4** package for nonlinear "mixed-effects" models, but the group-specific coefficients have flexible priors on their unknown covariance matrices.

`stan_gamm4` Similar to `gamm4` in the **gamm4** package, which augments a GLM (possibly with group-specific terms) with nonlinear smooth functions of the predictors to form a Generalized Additive Mixed Model (GAMM). Rather than calling `glmer` like `gamm4` does, `stan_gamm4` essentially calls `stan_glmer`, which avoids the optimization issues that often crop up with GAMMs and provides better estimates for the uncertainty of the parameter estimates.

`stan_polr` Similar to `polr` in the **MASS** package in that it models an ordinal response, but the Bayesian model also implies a prior distribution on the unknown cutpoints. Can also be used to model binary outcomes, possibly while estimating an unknown exponent governing the probability of success.

`stan_betareg` Similar to `betareg` in that it models an outcome that is a rate (proportion) but, rather than performing maximum likelihood estimation, full Bayesian estimation is performed by default, with customizable prior distributions for all parameters.

`stan_clogit` Similar to `clogit` in that it models a binary outcome where the number of successes and failures is fixed within each stratum by the research design. There are some minor syntactical differences relative to `clogit` that allow `stan_clogit` to accept group-specific terms as in `stan_glmer`.

`stan_mvmer` A multivariate form of `stan_glmer`, whereby the user can specify one or more submodels each consisting of a GLM with group-specific terms. If more than one submodel is specified (i.e. there is more than one outcome variable) then a dependence is induced by assuming that the group-specific terms for each grouping factor are correlated across submodels.

`stan_jm` Estimates shared parameter joint models for longitudinal and time-to-event (i.e. survival) data. The joint model can be univariate (i.e. one longitudinal outcome) or multivariate (i.e. more than one longitudinal outcome). A variety of parameterisations are available for linking the longitudinal and event processes (i.e. a variety of association structures).

See Also

<http://mc-stan.org/rstanarm/>

bayes_R2.stanreg	<i>Compute a Bayesian version of R-squared for regression models</i>
------------------	--

Description

Compute a Bayesian version of R-squared for regression models

Usage

```
## S3 method for class 'stanreg'
bayes_R2(object, newdata = NULL, re.form = NULL,
         offset = NULL, ...)
```

Arguments

object	A fitted model object returned by one of the rstanarm modeling functions. See stanreg-objects .
newdata	Similar to the newdata argument to posterior_linpred and posterior_predict except, in addition to new observations of the predictors, new observations of the <i>outcome</i> must be also included. See the Examples section below.
re.form, offset	For models with group-level terms, these arguments are passed to posterior_linpred if the newdata argument is specified.
...	Currently ignored.

Value

A vector of Bayesian R-squared values with length equal to the posterior sample size.

See Also

https://github.com/jgabry/bayes_R2

Examples

```
fit <- stan_glm(mpg ~ wt + cyl, data = mtcars, QR = TRUE, chains = 2)
rsq <- bayes_R2(fit)
print(median(rsq))

# specifying newdata (including outcome variable 'mpg')
nd <- data.frame(mpg = c(10, 20, 30), wt = c(4, 3, 2), cyl = c(8, 6, 4))
rsq_new <- bayes_R2(fit, newdata = nd)
print(median(rsq_new))
```

```
# multilevel binomial model
if (!exists("example_model")) example(example_model)
print(example_model)
median(bayes_R2(example_model))
median(bayes_R2(example_model, re.form = NA)) # exclude group-level
```

example_jm

Example joint longitudinal and time-to-event model

Description

A model for use in the **rstanarm** examples related to [stan_jm](#).

Format

Calling `example("example_jm")` will run the model in the Examples section, below, and the resulting `stanmvreg` object will then be available in the global environment. The `chains` and `iter` arguments are specified to make this example be small in size. In practice, we recommend that they be left unspecified in order to use the default values or increased if there are convergence problems. The `cores` argument is optional and on a multicore system, the user may well want to set that equal to the number of chains being executed.

Examples

```
set.seed(123)
example_jm <-
  stan_jm(formulaLong = logBili ~ year + (1 | id),
          dataLong = pbcLong[1:101,],
          formulaEvent = survival::Surv(futimeYears, death) ~ sex + trt,
          dataEvent = pbcSurv[1:15,],
          time_var = "year",
          # this next line is only to keep the example small in size!
          chains = 1, seed = 12345, iter = 200, refresh = 0)
```

example_model

Example model

Description

A model for use in **rstanarm** examples.

Format

Calling `example("example_model")` will run the model in the Examples section, below, and the resulting `stanreg` object will then be available in the global environment. The `chains` and `iter` arguments are specified to make this example be small in size. In practice, we recommend that they be left unspecified in order to use the default values (4 and 2000 respectively) or increased if there are convergence problems. The `cores` argument is optional and on a multicore system, the user may well want to set that equal to the number of chains being executed.

See Also

[cbpp](#) for a description of the data.

Examples

```
example_model <-
  stan_glmer(cbind(incidence, size - incidence) ~ size + period + (1|herd),
            data = lme4::cbpp, family = binomial, QR = TRUE,
            # this next line is only to keep the example small in size!
            chains = 2, cores = 1, seed = 12345, iter = 500, refresh = 0)
example_model
```

launch_shinystan.stanreg

Using the ShinyStan GUI with rstanarm models

Description

The ShinyStan interface provides visual and numerical summaries of model parameters and convergence diagnostics.

Usage

```
## S3 method for class 'stanreg'
launch_shinystan(object, ppd = TRUE, seed = 1234,
                model_name = NULL, note = NULL,
                rstudio = getOption("shinystan.rstudio"), ...)
```

Arguments

<code>object</code>	A fitted model object returned by one of the rstanarm modeling functions. See stanreg-objects .
<code>ppd</code>	Should rstanarm draw from the posterior predictive distribution before launching ShinyStan? The default is TRUE, although for very large objects it can be convenient to set it to FALSE as drawing from the posterior predictive distribution can be time consuming. If <code>ppd</code> is TRUE then graphical posterior predictive checks are available when ShinyStan is launched.
<code>seed</code>	Passed to pp_check (rstanarm) if <code>ppd</code> is TRUE.

model_name, note	Optional arguments passed to <code>as.shinystan</code> .
rstudio	Only relevant for 'RStudio' users. The default (FALSE) is to launch the app in the user's default web browser rather than the pop-up Viewer provided by 'RStudio'. Users can change the default to TRUE by setting the global option <code>options(shinystan.rstudio = TRUE)</code> .
...	Optional arguments passed to <code>runApp</code> .

Details

The `launch_shinystan` function will accept a `stanreg` object as input. Currently, almost any model fit using one of `rstanarm`'s model-fitting functions can be used with ShinyStan. The only exception is that ShinyStan does not currently support `rstanarm` models fit using `algorithm='optimizing'`. See the `shinystan` package documentation for more information.

Faster launch times

For some `rstanarm` models ShinyStan may take a very long time to launch. If this is the case with one of your models you may be able to speed up `launch_shinystan` in one of several ways:

Prevent ShinyStan from preparing graphical posterior predictive checks: When used with a `stanreg` object (`rstanarm` model object) ShinyStan will draw from the posterior predictive distribution and prepare graphical posterior predictive checks before launching. That way when you go to the PPcheck page the plots are immediately available. This can be time consuming for models fit to very large datasets and you can prevent this behavior by creating a `shinystan` object before calling `launch_shinystan`. To do this use `as.shinystan` with optional argument `ppd` set to FALSE (see the Examples section below). When you then launch ShinyStan and go to the PPcheck page the plots will no longer be automatically generated and you will be presented with the standard interface requiring you to first specify the appropriate y and $yrep$, which can be done for many but not all `rstanarm` models.

Use a `shinystan` object: Even if you don't want to prevent ShinyStan from preparing graphical posterior predictive checks, first creating a `shinystan` object using `as.shinystan` can reduce *future* launch times. That is, `launch_shinystan(sso)` will be faster than `launch_shinystan(fit)`, where `sso` is a `shinystan` object and `fit` is a `stanreg` object. It still may take some time for `as.shinystan` to create `sso` initially, but each time you subsequently call `launch_shinystan(sso)` it will reuse `sso` instead of internally creating a `shinystan` object every time. See the Examples section below.

References

Gabry, J., Simpson, D., Vehtari, A., Betancourt, M., and Gelman, A. (2018). Visualization in Bayesian workflow. *Journal of the Royal Statistical Society Series A*, accepted for publication. arXiv preprint: <http://arxiv.org/abs/1709.01449>.

Muth, C., Oravecz, Z., and Gabry, J. (2018) User-friendly Bayesian regression modeling: A tutorial with `rstanarm` and `shinystan`. *The Quantitative Methods for Psychology*. 14(2), 99–119. <https://www.tqmp.org/RegularArticles/vol14-2/p099/p099.pdf>

Examples

```

## Not run:
if (!exists("example_model")) example(example_model)

# Launch the ShinyStan app without saving the resulting shinystan object
if (interactive()) launch_shinystan(example_model)

# Launch the ShinyStan app (saving resulting shinystan object as sso)
if (interactive()) sso <- launch_shinystan(example_model)

# First create shinystan object then call launch_shinystan
sso <- shinystan::as.shinystan(example_model)
if (interactive()) launch_shinystan(sso)

# Prevent ShinyStan from preparing graphical posterior predictive checks that
# can be time consuming. example_model is small enough that it won't matter
# much here but in general this can help speed up launch_shinystan
sso <- shinystan::as.shinystan(example_model, ppd = FALSE)
if (interactive()) launch_shinystan(sso)

## End(Not run)

```

log_lik.stanreg

Pointwise log-likelihood matrix

Description

For models fit using MCMC only, the `log_lik` method returns the S by N pointwise log-likelihood matrix, where S is the size of the posterior sample and N is the number of data points, or in the case of the `stanmvreg` method (when called on `stan_jm` model objects) an S by $Npat$ matrix where $Npat$ is the number of individuals.

Usage

```

## S3 method for class 'stanreg'
log_lik(object, newdata = NULL, offset = NULL, ...)

## S3 method for class 'stanmvreg'
log_lik(object, m = 1, newdata = NULL, ...)

## S3 method for class 'stanjm'
log_lik(object, newdataLong = NULL,
        newdataEvent = NULL, ...)

```

Arguments

object	A fitted model object returned by one of the rstanarm modeling functions. See stanreg-objects .
newdata	An optional data frame of new data (e.g. holdout data) to use when evaluating the log-likelihood. See the description of newdata for posterior_predict .
offset	A vector of offsets. Only required if newdata is specified and an offset was specified when fitting the model.
...	Currently ignored.
m	Integer specifying the number or name of the submodel
newdataLong, newdataEvent	Optional data frames containing new data (e.g. holdout data) to use when evaluating the log-likelihood for a model estimated using stan_jm . If the fitted model was a multivariate joint model (i.e. more than one longitudinal outcome), then newdataLong is allowed to be a list of data frames. If supplying new data, then newdataEvent should also include variables corresponding to the event time and event indicator as these are required for evaluating the log likelihood for the event submodel. For more details, see the description of newdataLong and newdataEvent for posterior_survfit .

Value

For the stanreg and stanmvreg methods an S by N matrix, where S is the size of the posterior sample and N is the number of data points. For the stanjm method an S by $Npat$ matrix where $Npat$ is the number of individuals.

Examples

```

roaches$roach100 <- roaches$roach1 / 100
fit <- stan_glm(
  y ~ roach100 + treatment + senior,
  offset = log(exposure2),
  data = roaches,
  family = poisson(link = "log"),
  prior = normal(0, 2.5),
  prior_intercept = normal(0, 10),
  iter = 500 # to speed up example
)
l1 <- log_lik(fit)
dim(l1)
all.equal(ncol(l1), nobs(fit))

# using newdata argument
nd <- roaches[1:2, ]
nd$treatment[1:2] <- c(0, 1)
l12 <- log_lik(fit, newdata = nd, offset = c(0, 0))
head(l12)
dim(l12)
all.equal(ncol(l12), nrow(nd))

```


Description

For models fit using MCMC, compute approximate leave-one-out cross-validation (LOO, LOOIC) or, less preferably, the Widely Applicable Information Criterion (WAIC) using the **loo** package. Functions for K -fold cross-validation, model comparison, and model weighting/averaging are also provided. **Note:** these functions are not guaranteed to work properly unless the `data` argument was specified when the model was fit. Also, as of **loo** version 2.0.0 the default number of cores is now only 1, but we recommend using as many (or close to as many) cores as possible by setting the `cores` argument or using `options(mc.cores = VALUE)` to set it for an entire session.

Usage

```
## S3 method for class 'stanreg'
loo(x, ..., cores = getOption("mc.cores", 1),
    save_psis = FALSE, k_threshold = NULL)

## S3 method for class 'stanreg'
waic(x, ...)

kfold(x, K = 10, save_fits = FALSE, folds = NULL)

compare_models(..., loos = list(), detail = FALSE)

## S3 method for class 'stanreg_list'
loo_model_weights(x, ...,
    cores = getOption("mc.cores", 1), k_threshold = NULL)
```

Arguments

<code>x</code>	For <code>loo</code> , <code>waic</code> , and <code>kfold</code> methods, a fitted model object returned by one of the <code>rstanarm</code> modeling functions. See stanreg-objects . For <code>loo_model_weights</code> , <code>x</code> should be a "stanreg_list" object, which is a list of fitted model objects created by <code>stanreg_list</code> .
<code>...</code>	For <code>compare_models</code> , <code>...</code> should contain two or more objects returned by the <code>loo</code> , <code>kfold</code> , or <code>waic</code> method (see the Examples section, below). For <code>loo_model_weights</code> , <code>...</code> should contain arguments (e.g. method) to pass to the default <code>loo_model_weights</code> method from the loo package.
<code>cores</code> , <code>save_psis</code>	Passed to <code>loo</code> .

k_threshold	Threshold for flagging estimates of the Pareto shape parameters k estimated by loo. See the <i>How to proceed when loo gives warnings</i> section, below, for details.
K	For kfold, the number of subsets (folds) into which the data will be partitioned for performing K -fold cross-validation. The model is refit K times, each time leaving out one of the K folds. If K is equal to the total number of observations in the data then K -fold cross-validation is equivalent to exact leave-one-out cross-validation.
save_fits	For kfold, if TRUE, a component 'fits' is added to the returned object to store the cross-validated stanreg objects and the indices of the omitted observations for each fold. Defaults to FALSE.
folds	For kfold, an optional integer vector with one element per observation in the data used to fit the model. Each element of the vector is an integer in $1:K$ indicating to which of the K folds the corresponding observation belongs. There are some convenience functions available in the loo package that create integer vectors to use for this purpose (see the Examples section below and also the kfold-helpers page). If folds is not specified then the default is to call <code>loo::kfold_split_random</code> to randomly partition the data into K subsets of equal (or as close to equal as possible) size.
loos	For compare_models, a list of two or more objects returned by the loo, kfold, or waic method. This argument can be used as an alternative to passing these objects via <code>...</code>
detail	For compare_models, if TRUE then extra information about each model (currently just the model formulas) will be printed with the output.

Value

The structure of the objects returned by loo and waic methods are documented in detail in the **Value** section in [loo](#) and [waic](#) (from the **loo** package).

kfold returns an object with classes 'kfold' and 'loo' that has a similar structure as the objects returned by the loo and waic methods.

compare_models returns a vector or matrix with class 'compare.loo'. See the **Comparing models** section below for more details.

Approximate LOO CV

The loo method for stanreg objects provides an interface to the **loo** package for approximate leave-one-out cross-validation (LOO). The LOO Information Criterion (LOOIC) has the same purpose as the Akaike Information Criterion (AIC) that is used by frequentists. Both are intended to estimate the expected log predictive density (ELPD) for a new dataset. However, the AIC ignores priors and assumes that the posterior distribution is multivariate normal, whereas the functions from the **loo** package do not make this distributional assumption and integrate over uncertainty in the parameters. This only assumes that any one observation can be omitted without having a major effect on the posterior distribution, which can be judged using the diagnostic plot provided by the [plot.loo](#) method and the warnings provided by the [print.loo](#) method (see the *How to Use the rstanarm Package* vignette for an example of this process).

How to proceed when loo gives warnings (k_threshold): The `k_threshold` argument to the `loo` method for `rstanarm` models is provided as a possible remedy when the diagnostics reveal problems stemming from the posterior's sensitivity to particular observations. Warnings about Pareto k estimates indicate observations for which the approximation to LOO is problematic (this is described in detail in Vehtari, Gelman, and Gabry (2017) and the `loo` package documentation). The `k_threshold` argument can be used to set the k value above which an observation is flagged. If `k_threshold` is not NULL and there are J observations with k estimates above `k_threshold` then when `loo` is called it will refit the original model J times, each time leaving out one of the J problematic observations. The pointwise contributions of these observations to the total ELPD are then computed directly and substituted for the previous estimates from these J observations that are stored in the object created by `loo`.

Note: in the warning messages issued by `loo` about large Pareto k estimates we recommend setting `k_threshold` to at least 0.7. There is a theoretical reason, explained in Vehtari, Gelman, and Gabry (2017), for setting the threshold to the stricter value of 0.5, but in practice they find that errors in the LOO approximation start to increase non-negligibly when $k > 0.7$.

K-fold CV

The `kfold` function performs exact K -fold cross-validation. First the data are randomly partitioned into K subsets of equal (or as close to equal as possible) size (unless the folds are specified manually). Then the model is refit K times, each time leaving out one of the K subsets. If K is equal to the total number of observations in the data then K -fold cross-validation is equivalent to exact leave-one-out cross-validation (to which `loo` is an efficient approximation). The `compare_models` function is also compatible with the objects returned by `kfold`.

Comparing models

`compare_models` is a method for the `compare` function in the `loo` package that performs some extra checks to make sure the `rstanarm` models are suitable for comparison. These extra checks include verifying that all models to be compared were fit using the same outcome variable and likelihood family.

If exactly two models are being compared then `compare_models` returns a vector containing the difference in expected log predictive density (ELPD) between the models and the standard error of that difference (the documentation for `compare` in the `loo` package has additional details about the calculation of the standard error of the difference). The difference in ELPD will be negative if the expected out-of-sample predictive accuracy of the first model is higher. If the difference is positive then the second model is preferred.

If more than two models are being compared then `compare_models` returns a matrix with one row per model. This matrix summarizes the objects and arranges them in descending order according to expected out-of-sample predictive accuracy. That is, the first row of the matrix will be for the model with the largest ELPD (smallest LOOIC). The columns containing the ELPD difference and the standard error of the difference contain values relative to the model with the best ELPD. See the **Details** section at the `compare` page in the `loo` package for more information.

Model weights

The `loo_model_weights` method can be used to compute model weights for a "stanreg_list" object, which is a list of fitted model objects made with `stanreg_list`. The end of the **Examples**

section has a demonstration. For details see the `loo_model_weights` documentation in the `loo` package.

References

Vehtari, A., Gelman, A., and Gabry, J. (2017). Practical Bayesian model evaluation using leave-one-out cross-validation and WAIC. *Statistics and Computing*. 27(5), 1413–1432. doi:10.1007/s11222-016-9696-4. arXiv preprint: <http://arxiv.org/abs/1507.04544/>

Yao, Y., Vehtari, A., Simpson, D., and Gelman, A. (2018) Using stacking to average Bayesian predictive distributions. *Bayesian Analysis*, advance publication, doi:10.1214/17-BA1091. ([online](#)).

Gabry, J., Simpson, D., Vehtari, A., Betancourt, M., and Gelman, A. (2018). Visualization in Bayesian workflow. *Journal of the Royal Statistical Society Series A*, accepted for publication. arXiv preprint: <http://arxiv.org/abs/1709.01449>.

See Also

- The new `loo` package vignettes and various `rstanarm` vignettes for more examples using `loo` and related functions with `rstanarm` models.
- `pareto-k-diagnostic` in the `loo` package for more on Pareto k diagnostics.
- `log_lik.stanreg` to directly access the pointwise log-likelihood matrix.

Examples

```
fit1 <- stan_glm(mpg ~ wt, data = mtcars)
fit2 <- stan_glm(mpg ~ wt + cyl, data = mtcars)

# compare on LOOIC
# (for bigger models use as many cores as possible)
loo1 <- loo(fit1, cores = 2)
print(loo1)
loo2 <- loo(fit2, cores = 2)
print(loo2)

# when comparing exactly two models, the reported 'elpd_diff'
# will be positive if the expected predictive accuracy for the
# second model is higher. the approximate standard error of the
# difference is also reported.
compare_models(loo1, loo2)
compare_models(loos = list(loo1, loo2)) # can also provide list

# when comparing three or more models they are ordered by
# expected predictive accuracy. elpd_diff and se_diff are relative
# to the model with best elpd_loo (first row)
fit3 <- stan_glm(mpg ~ disp * as.factor(cyl), data = mtcars)
loo3 <- loo(fit3, cores = 2, k_threshold = 0.7)
compare_models(loo1, loo2, loo3)

# setting detail=TRUE will also print model formulas
compare_models(loo1, loo2, loo3, detail=TRUE)
```

```

# Computing model weights
model_list <- stanreg_list(fit1, fit2, fit3)
loo_model_weights(model_list, cores = 2) # can specify k_threshold=0.7 if necessary

# if you have already computed loo then it's more efficient to pass a list
# of precomputed loo objects than a "stanreg_list", avoiding the need
# for loo_model_weights to call loo() internally
loo_list <- list(fit1 = loo1, fit2 = loo2, fit3 = loo3) # names optional (affects printing)
loo_model_weights(loo_list)

# 10-fold cross-validation
(kfold1 <- kfold(fit1, K = 10))
kfold2 <- kfold(fit2, K = 10)
compare_models(kfold1, kfold2, detail=TRUE)

# Cross-validation stratifying by a grouping variable
# (note: might get some divergences warnings with this model but
# this is just intended as a quick example of how to code this)
library(loo)
fit4 <- stan_lmer(mpg ~ disp + (1|cyl), data = mtcars)
table(mtcars$cyl)
folds_cyl <- kfold_split_stratified(K = 3, x = mtcars$cyl)
table(cyl = mtcars$cyl, fold = folds_cyl)
kfold4 <- kfold(fit4, K = 3, folds = folds_cyl)

```

loo_predict.stanreg *Compute weighted expectations using LOO*

Description

These functions are wrappers around the [E_loo](#) function (**loo** package) that provide compatibility for **rstanarm** models.

Usage

```

## S3 method for class 'stanreg'
loo_predict(object, type = c("mean", "var",
  "quantile"), probs = 0.5, ..., psis_object = NULL)

## S3 method for class 'stanreg'
loo_linpred(object, type = c("mean", "var",
  "quantile"), probs = 0.5, transform = FALSE, ...,
  psis_object = NULL)

## S3 method for class 'stanreg'
loo_predictive_interval(object, prob = 0.9, ...,
  psis_object = NULL)

```

Arguments

object	A fitted model object returned by one of the rstanarm modeling functions. See stanreg-objects .
type	The type of expectation to compute. The options are "mean", "variance", and "quantile".
probs	For computing quantiles, a vector of probabilities.
...	Currently unused.
psis_object	An object returned by psis . If missing then psis will be run internally, which may be time consuming for models fit to very large datasets.
transform	Passed to posterior_linpred .
prob	For <code>loo_predictive_interval</code> , a scalar in (0, 1) indicating the desired probability mass to include in the intervals. The default is <code>prob=0.9</code> (90% intervals).

Value

A list with elements `value` and `pareto_k`.

For `loo_predict` and `loo_linpred` the value component is a vector with one element per observation.

For `loo_predictive_interval` the value component is a matrix with one row per observation and two columns (like [predictive_interval](#)). `loo_predictive_interval(..., prob = p)` is equivalent to `loo_predict(..., type = "quantile", probs = c(a, 1-a))` with `a = (1 - p)/2`, except it transposes the result and adds informative column names.

See [E_loo](#) and [pareto-k-diagnostic](#) for details on the `pareto_k` diagnostic.

References

- Vehtari, A., Gelman, A., and Gabry, J. (2017). Practical Bayesian model evaluation using leave-one-out cross-validation and WAIC. *Statistics and Computing*. 27(5), 1413–1432. doi:10.1007/s11222-016-9696-4. arXiv preprint: <http://arxiv.org/abs/1507.04544/>
- Yao, Y., Vehtari, A., Simpson, D., and Gelman, A. (2018) Using stacking to average Bayesian predictive distributions. *Bayesian Analysis*, advance publication, doi:10.1214/17-BA1091. ([online](#)).
- Gabry, J., Simpson, D., Vehtari, A., Betancourt, M., and Gelman, A. (2018). Visualization in Bayesian workflow. *Journal of the Royal Statistical Society Series A*, accepted for publication. arXiv preprint: <http://arxiv.org/abs/1709.01449>.

Examples

```
## Not run:
if (!exists("example_model")) example(example_model)

# optionally, log-weights can be pre-computed and reused
psis_result <- loo::psis(log_ratios = -log_lik(example_model))

loo_probs <- loo_linpred(example_model, type = "mean", transform = TRUE, psis_object = psis_result)
str(loo_probs)
```

```

loo_pred_var <- loo_predict(example_model, type = "var", psis_object = psis_result)
str(loo_pred_var)

loo_pred_ints <- loo_predictive_interval(example_model, prob = 0.8, psis_object = psis_result)
str(loo_pred_ints)

## End(Not run)

```

neg_binomial_2

Family function for negative binomial GLMs

Description

Specifies the information required to fit a Negative Binomial GLM in a similar way to [negative.binomial](#). However, here the overdispersion parameter θ is not specified by the user and always estimated (really the *reciprocal* of the dispersion parameter is estimated). A call to this function can be passed to the family argument of [stan_glm](#) or [stan_glmer](#) to estimate a Negative Binomial model. Alternatively, the [stan_glm.nb](#) and [stan_glmer.nb](#) wrapper functions may be used, which call `neg_binomial_2` internally.

Usage

```
neg_binomial_2(link = "log")
```

Arguments

`link` The same as for [poisson](#), typically a character vector of length one among "log", "identity", and "sqrt".

Value

An object of class [family](#) very similar to that of [poisson](#) but with a different family name.

Examples

```

if (!grepl("^sparc", R.version$platform))
  stan_glm(Days ~ Sex/(Age + Eth*Lrn), data = MASS::quine, seed = 123,
          family = neg_binomial_2, QR = TRUE, algorithm = "optimizing")

# or, equivalently, call stan_glm.nb() without specifying the family

```

pairs.stanreg

*Pairs method for stanreg objects***Description**

Interface to **bayesplot**'s `mcmc_pairs` function for use with **rstanarm** models. Be careful not to specify too many parameters to include or the plot will be both hard to read and slow to render.

Usage

```
## S3 method for class 'stanreg'
pairs(x, pars = NULL, regex_pars = NULL,
      condition = pairs_condition(nuts = "accept_stat__"), ...)
```

Arguments

x	A fitted model object returned by one of the rstanarm modeling functions. See stanreg-objects .
pars	An optional character vector of parameter names. All parameters are included by default, but for models with more than just a few parameters it may be far too many to visualize on a small computer screen and also may require substantial computing time.
regex_pars	An optional character vector of regular expressions to use for parameter selection. <code>regex_pars</code> can be used in place of <code>pars</code> or in addition to <code>pars</code> . Currently, all functions that accept a <code>regex_pars</code> argument ignore it for models fit using optimization.
condition	Same as the <code>condition</code> argument to <code>mcmc_pairs</code> except the <i>default is different</i> for rstanarm models. By default, the <code>mcmc_pairs</code> function in the bayesplot package plots some of the Markov chains (half, in the case of an even number of chains) in the panels above the diagonal and the other half in the panels below the diagonal. However since we know that rstanarm models were fit using Stan (which bayesplot doesn't assume) we can make the default more useful by splitting the draws according to the <code>accept_stat__</code> diagnostic. The plots below the diagonal will contain realizations that are below the median <code>accept_stat__</code> and the plots above the diagonal will contain realizations that are above the median <code>accept_stat__</code> . To change this behavior see the documentation of the <code>condition</code> argument at mcmc_pairs .
...	Optional arguments passed to <code>mcmc_pairs</code> . The <code>np</code> , <code>lp</code> , and <code>max_treedepth</code> arguments to <code>mcmc_pairs</code> are handled automatically by rstanarm and do not need to be specified by the user in <code>...</code> . The arguments that can be specified in <code>...</code> include <code>transformations</code> , <code>diag_fun</code> , <code>off_diag_fun</code> , <code>diag_args</code> , <code>off_diag_args</code> , and <code>np_style</code> . These arguments are documented thoroughly on the help page for mcmc_pairs .

Examples

```

if (!exists("example_model")) example(example_model)

bayesplot::color_scheme_set("purple")

# see 'condition' argument above for details on the plots below and
# above the diagonal. default is to split by accept_stat__
pairs(example_model, pars = c("(Intercept)", "log-posterior"))

pairs(
  example_model,
  regex_pars = "herd:[2,7,9]",
  diag_fun = "dens",
  off_diag_fun = "hex"
)

# for demonstration purposes, intentionally fit a model that
# will (almost certainly) have some divergences
fit <- stan_glm(
  mpg ~ ., data = mtcars,
  iter = 1000,
  # this combo of prior and adapt_delta should lead to some divergences
  prior = hs(),
  adapt_delta = 0.9
)

pairs(fit, pars = c("wt", "sigma", "log-posterior"))

pairs(
  fit,
  pars = c("wt", "sigma", "log-posterior"),
  transformations = list(sigma = "log"), # show log(sigma) instead of sigma
  off_diag_fun = "hex" # use hexagonal heatmaps instead of scatterplots
)

bayesplot::color_scheme_set("brightblue")
pairs(
  fit,
  pars = c("(Intercept)", "wt", "sigma", "log-posterior"),
  transformations = list(sigma = "log"),
  off_diag_args = list(size = 3/4, alpha = 1/3), # size and transparency of scatterplot points
  np_style = pairs_style_np(div_color = "black", div_shape = 2) # color and shape of the divergences
)

# Using the condition argument to show divergences above the diagonal
pairs(
  fit,
  pars = c("(Intercept)", "wt", "log-posterior"),

```

```

    condition = pairs_condition(nuts = "divergent__")
  )

```

plot.predict.stanjm *Plot the estimated subject-specific or marginal longitudinal trajectory*

Description

This generic plot method for `predict.stanjm` objects will plot the estimated subject-specific or marginal longitudinal trajectory using the data frame returned by a call to `posterior_traj`. To ensure that enough data points are available to plot the longitudinal trajectory, it is assumed that the call to `posterior_traj` would have used the default `interpolate = TRUE`, and perhaps also `extrapolate = TRUE` (the latter being optional, depending on whether or not the user wants to see extrapolation of the longitudinal trajectory beyond the last observation time).

Usage

```

## S3 method for class 'predict.stanjm'
plot(x, ids = NULL, limits = c("ci", "pi",
  "none"), xlab = NULL, ylab = NULL, vline = FALSE,
  plot_observed = FALSE, facet_scales = "free_x",
  ci_geom_args = NULL, grp_overlay = FALSE, ...)

```

Arguments

<code>x</code>	A data frame and object of class <code>predict.stanjm</code> returned by a call to the function <code>posterior_traj</code> . The object contains point estimates and uncertainty interval limits for the fitted values of the longitudinal response.
<code>ids</code>	An optional vector providing a subset of subject IDs for whom the predicted curves should be plotted.
<code>limits</code>	A quoted character string specifying the type of limits to include in the plot. Can be one of: <code>"ci"</code> for the Bayesian posterior uncertainty interval for the estimated mean longitudinal response (often known as a credible interval); <code>"pi"</code> for the prediction interval for the estimated (raw) longitudinal response; or <code>"none"</code> for no interval limits.
<code>xlab, ylab</code>	An optional axis label passed to <code>labs</code> .
<code>vline</code>	A logical. If <code>TRUE</code> then a vertical dashed line is added to the plot indicating the event or censoring time for the individual. Can only be used if each plot within the figure is for a single individual.
<code>plot_observed</code>	A logical. If <code>TRUE</code> then the observed longitudinal measurements are overlaid on the plot.
<code>facet_scales</code>	A character string passed to the <code>scales</code> argument of <code>facet_wrap</code> when plotting the longitudinal trajectory for more than one individual.

ci_geom_args	Optional arguments passed to geom_ribbon and used to control features of the plotted interval limits. They should be supplied as a named list.
grp_overlay	Only relevant if the model had lower level units clustered within an individual. If TRUE, then the fitted trajectories for the lower level units will be overlaid in the same plot region (that is, all lower level units for a single individual will be shown within a single facet). If FALSE, then the fitted trajectories for each lower level unit will be shown in a separate facet.
...	Optional arguments passed to geom_smooth and used to control features of the plotted longitudinal trajectory.

Value

A ggplot object, also of class `plot.predict.stanjm`. This object can be further customised using the [ggplot2](#) package. It can also be passed to the function [plot_stack_jm](#).

See Also

[posterior_traj](#), [plot_stack_jm](#), [posterior_survfit](#), [plot.survfit.stanjm](#)

Examples

```
# Run example model if not already loaded
if (!exists("example_jm")) example(example_jm)

# For a subset of individuals in the estimation dataset we will
# obtain subject-specific predictions for the longitudinal submodel
# at evenly spaced times between 0 and their event or censoring time.
pt1 <- posterior_traj(example_jm, ids = c(7,13,15), interpolate = TRUE)
plot(pt1) # credible interval for mean response
plot(pt1, limits = "pi") # prediction interval for raw response
plot(pt1, limits = "none") # no uncertainty interval

# We can also extrapolate the longitudinal trajectories.
pt2 <- posterior_traj(example_jm, ids = c(7,13,15), interpolate = TRUE,
  extrapolate = TRUE)
plot(pt2)
plot(pt2, vline = TRUE) # add line indicating event or censoring time
plot(pt2, vline = TRUE, plot_observed = TRUE) # overlay observed longitudinal data

# We can change or add attributes to the plot
plot1 <- plot(pt2, ids = c(7,13,15), xlab = "Follow up time",
  vline = TRUE, plot_observed = TRUE,
  facet_scales = "fixed", color = "blue", linetype = 2,
  ci_geom_args = list(fill = "red"))
plot1

# Since the returned plot is also a ggplot object, we can
# modify some of its attributes after it has been returned
plot1 +
  ggplot2::theme(strip.background = ggplot2::element_blank()) +
```

```
ggplot2::labs(title = "Some plotted longitudinal trajectories")
```

plot.stanreg

Plot method for stanreg objects

Description

The plot method for [stanreg-objects](#) provides a convenient interface to the [MCMC](#) module in the [bayesplot](#) package for plotting MCMC draws and diagnostics. It is also straightforward to use the functions from the [bayesplot](#) package directly rather than via the plot method. Examples of both methods of plotting are given below.

Usage

```
## S3 method for class 'stanreg'
plot(x, plotfun = "intervals", pars = NULL,
     regex_pars = NULL, ...)
```

Arguments

x	A fitted model object returned by one of the rstanarm modeling functions. See stanreg-objects .
plotfun	A character string naming the bayesplot MCMC function to use. The default is to call mcmc_intervals . plotfun can be specified either as the full name of a bayesplot plotting function (e.g. "mcmc_hist") or can be abbreviated to the part of the name following the "mcmc_" prefix (e.g. "hist"). To get the names of all available MCMC functions see available_mcmc .
pars	An optional character vector of parameter names.
regex_pars	An optional character vector of regular expressions to use for parameter selection. regex_pars can be used in place of pars or in addition to pars. Currently, all functions that accept a regex_pars argument ignore it for models fit using optimization.
...	Additional arguments to pass to plotfun for customizing the plot. These are described on the help pages for the individual plotting functions. For example, the arguments accepted for the default plotfun="intervals" can be found at mcmc_intervals .

Value

Either a ggplot object that can be further customized using the **ggplot2** package, or an object created from multiple ggplot objects (e.g. a gtable object created by [arrangeGrob](#)).

References

Gabry, J., Simpson, D., Vehtari, A., Betancourt, M., and Gelman, A. (2018). Visualization in Bayesian workflow. *Journal of the Royal Statistical Society Series A*, accepted for publication. arXiv preprint: <http://arxiv.org/abs/1709.01449>.

See Also

- The vignettes in the **bayesplot** package for many examples.
- [MCMC-overview](#) (**bayesplot**) for links to the documentation for all the available plotting functions.
- [color_scheme_set](#) (**bayesplot**) to change the color scheme used for plotting.
- [pp_check](#) for graphical posterior predictive checks.
- [plot_nonlinear](#) for models with nonlinear smooth functions fit using [stan_gamm4](#).

Examples

```
# Use rstanarm example model
if (!exists("example_model")) example(example_model)
fit <- example_model

#####
### Intervals and point estimates ###
#####
plot(fit) # same as plot(fit, "intervals"), plot(fit, "mcmc_intervals")

p <- plot(fit, pars = "size", regex_pars = "period",
          prob = 0.5, prob_outer = 0.9)
p + ggplot2::ggtitle("Posterior medians \n with 50% and 90% intervals")

# Shaded areas under densities
bayesplot::color_scheme_set("brightblue")
plot(fit, "areas", regex_pars = "period",
      prob = 0.5, prob_outer = 0.9)

# Make the same plot by extracting posterior draws and calling
# bayesplot::mcmc_areas directly
x <- as.array(fit, regex_pars = "period")
bayesplot::mcmc_areas(x, prob = 0.5, prob_outer = 0.9)

#####
### Histograms & density plots ###
#####
plot_title <- ggplot2::ggtitle("Posterior Distributions")
plot(fit, "hist", regex_pars = "period") + plot_title
plot(fit, "dens_overlay", pars = "(Intercept)",
      regex_pars = "period") + plot_title

#####
### Scatterplots ###
#####
bayesplot::color_scheme_set("teal")
plot(fit, "scatter", pars = paste0("period", 2:3))
plot(fit, "scatter", pars = c("(Intercept)", "size"),
      size = 3, alpha = 0.5) +
```

```

ggplot2::stat_ellipse(level = 0.9)

#####
### Rhat, effective sample size, autocorrelation ###
#####
bayesplot::color_scheme_set("red")

# rhat
plot(fit, "rhat")
plot(fit, "rhat_hist")

# ratio of effective sample size to total posterior sample size
plot(fit, "neff")
plot(fit, "neff_hist")

# autocorrelation by chain
plot(fit, "acf", pars = "(Intercept)", regex_pars = "period")
plot(fit, "acf_bar", pars = "(Intercept)", regex_pars = "period")

#####
### Traceplots ###
#####
# NOTE: rstanarm doesn't store the warmup draws (to save space because they
# are not so essential for diagnosing the particular models implemented in
# rstanarm) so the iterations in the traceplot are post-warmup iterations

bayesplot::color_scheme_set("pink")
(trace <- plot(fit, "trace", pars = "(Intercept)"))

# change traceplot colors to ggplot defaults or custom values
trace + ggplot2::scale_color_discrete()
trace + ggplot2::scale_color_manual(values = c("maroon", "skyblue2"))

# changing facet layout
plot(fit, "trace", pars = c("(Intercept)", "period2"),
     facet_args = list(nrow = 2))
# same plot by calling bayesplot::mcmc_trace directly
x <- as.array(fit, pars = c("(Intercept)", "period2"))
bayesplot::mcmc_trace(x, facet_args = list(nrow = 2))

#####
### More ###
#####

# regex_pars examples
plot(fit, regex_pars = "herd:1\\")
plot(fit, regex_pars = "herd:[279]")
plot(fit, regex_pars = "herd:[279]|period2")
plot(fit, regex_pars = c("herd:[279]", "period2"))

```

```
# For graphical posterior predictive checks see
# help("pp_check.stanreg")
```

plot.survfit.stanjm *Plot the estimated subject-specific or marginal survival function*

Description

This generic plot method for `survfit.stanjm` objects will plot the estimated subject-specific or marginal survival function using the data frame returned by a call to `posterior_survfit`. The call to `posterior_survfit` should ideally have included an "extrapolation" of the survival function, obtained by setting the `extrapolate` argument to `TRUE`.

The `plot_stack_jm` function takes arguments containing the plots of the estimated subject-specific longitudinal trajectory (or trajectories if a multivariate joint model was estimated) and the plot of the estimated subject-specific survival function and combines them into a single figure. This is most easily understood by running the **Examples** below.

Usage

```
## S3 method for class 'survfit.stanjm'
plot(x, ids = NULL, limits = c("ci", "none"),
     xlab = NULL, ylab = NULL, facet_scales = "free",
     ci_geom_args = NULL, ...)

plot_stack_jm(yplot, survplot)
```

Arguments

<code>x</code>	A data frame and object of class <code>survfit.stanjm</code> returned by a call to the function <code>posterior_survfit</code> . The object contains point estimates and uncertainty interval limits for estimated values of the survival function.
<code>ids</code>	An optional vector providing a subset of subject IDs for whom the predicted curves should be plotted.
<code>limits</code>	A quoted character string specifying the type of limits to include in the plot. Can be one of: "ci" for the Bayesian posterior uncertainty interval for the estimated survival probability (often known as a credible interval); or "none" for no interval limits.
<code>xlab, ylab</code>	An optional axis label passed to <code>labs</code> .
<code>facet_scales</code>	A character string passed to the <code>scales</code> argument of <code>facet_wrap</code> when plotting the longitudinal trajectory for more than one individual.
<code>ci_geom_args</code>	Optional arguments passed to <code>geom_ribbon</code> and used to control features of the plotted interval limits. They should be supplied as a named list.
<code>...</code>	Optional arguments passed to <code>geom_line</code> and used to control features of the plotted survival function.

<code>yplot</code>	An object of class <code>plot.predict.stanjm</code> , returned by a call to the generic <code>plot</code> method for objects of class <code>predict.stanjm</code> . If there is more than one longitudinal outcome, then a list of such objects can be provided.
<code>survplot</code>	An object of class <code>plot.survfit.stanjm</code> , returned by a call to the generic <code>plot</code> method for objects of class <code>survfit.stanjm</code> .

Value

The `plot` method returns a `ggplot` object, also of class `plot.survfit.stanjm`. This object can be further customised using the **ggplot2** package. It can also be passed to the function `plot_stack_jm`. `plot_stack_jm` returns an object of class `bayesplot_grid` that includes plots of the estimated subject-specific longitudinal trajectories stacked on top of the associated subject-specific survival curve.

See Also

[posterior_survfit](#), [plot_stack_jm](#), [posterior_traj](#), [plot.predict.stanjm](#)
[plot.predict.stanjm](#), [plot.survfit.stanjm](#), [posterior_predict](#), [posterior_survfit](#)

Examples

```
# Run example model if not already loaded
if (!exists("example_jm")) example(example_jm)

# Obtain subject-specific conditional survival probabilities
# for all individuals in the estimation dataset.
ps1 <- posterior_survfit(example_jm, extrapolate = TRUE)

# We then plot the conditional survival probabilities for
# a subset of individuals
plot(ps1, ids = c(7,13,15))
# We can change or add attributes to the plot
plot(ps1, ids = c(7,13,15), limits = "none")
plot(ps1, ids = c(7,13,15), xlab = "Follow up time")
plot(ps1, ids = c(7,13,15), ci_geom_args = list(fill = "red"),
      color = "blue", linetype = 2)
plot(ps1, ids = c(7,13,15), facet_scales = "fixed")

# Since the returned plot is also a ggplot object, we can
# modify some of its attributes after it has been returned
plot1 <- plot(ps1, ids = c(7,13,15))
plot1 +
  ggplot2::theme(strip.background = ggplot2::element_blank()) +
  ggplot2::coord_cartesian(xlim = c(0, 15)) +
  ggplot2::labs(title = "Some plotted survival functions")

# We can also combine the plot(s) of the estimated
# subject-specific survival functions, with plot(s)
# of the estimated longitudinal trajectories for the
# same individuals
```



```

ps1 <- posterior_survfit(example_jm, ids = c(7,13,15))
pt1 <- posterior_traj(example_jm, , ids = c(7,13,15))
plot_surv <- plot(ps1)
plot_traj <- plot(pt1, vline = TRUE, plot_observed = TRUE)
plot_stack_jm(plot_traj, plot_surv)

# Lastly, let us plot the standardised survival function
# based on all individuals in our estimation dataset
ps2 <- posterior_survfit(example_jm, standardise = TRUE, times = 0,
                        control = list(epoints = 20))
plot(ps2)

if (!exists("example_jm")) example(example_jm)
ps1 <- posterior_survfit(example_jm, ids = c(7,13,15))
pt1 <- posterior_traj(example_jm, ids = c(7,13,15), extrapolate = TRUE)
plot_surv <- plot(ps1)
plot_traj <- plot(pt1, vline = TRUE, plot_observed = TRUE)
plot_stack_jm(plot_traj, plot_surv)

```

posterior_interval.stanreg

Posterior uncertainty intervals

Description

For models fit using MCMC (algorithm="sampling") or one of the variational approximations ("meanfield" or "fullrank"), the `posterior_interval` function computes Bayesian posterior uncertainty intervals. These intervals are often referred to as *credible* intervals, but we use the term *uncertainty* intervals to highlight the fact that wider intervals correspond to greater uncertainty.

Usage

```

## S3 method for class 'stanreg'
posterior_interval(object, prob = 0.9,
                  type = "central", pars = NULL, regex_pars = NULL, ...)

```

Arguments

object	A fitted model object returned by one of the rstanarm modeling functions. See stanreg-objects .
prob	A number $p \in (0, 1)$ indicating the desired probability mass to include in the intervals. The default is to report 90% intervals (prob=0.9) rather than the traditionally used 95% (see Details).

type	The type of interval to compute. Currently the only option is "central" (see Details). A central 100p% interval is defined by the $\alpha/2$ and $1 - \alpha/2$ quantiles, where $\alpha = 1 - p$.
pars	An optional character vector of parameter names.
regex_pars	An optional character vector of regular expressions to use for parameter selection. regex_pars can be used in place of pars or in addition to pars. Currently, all functions that accept a regex_pars argument ignore it for models fit using optimization.
...	Currently ignored.

Details

Interpretation: Unlike for a frequentist confidence interval, it is valid to say that, conditional on the data and model, we believe that with probability p the value of a parameter is in its 100p% posterior interval. This intuitive interpretation of Bayesian intervals is often erroneously applied to frequentist confidence intervals. See Morey et al. (2015) for more details on this issue and the advantages of using Bayesian posterior uncertainty intervals (also known as credible intervals).

Default 90% intervals: We default to reporting 90% intervals rather than 95% intervals for several reasons:

- Computational stability: 90% intervals are more stable than 95% intervals (for which each end relies on only 2.5% of the posterior draws).
- Relation to Type-S errors (Gelman and Carlin, 2014): 95% of the mass in a 90% central interval is above the lower value (and 95% is below the upper value). For a parameter θ , it is therefore easy to see if the posterior probability that $\theta > 0$ (or $\theta < 0$) is larger or smaller than 95%.

Of course, if 95% intervals are desired they can be computed by specifying `prob=0.95`.

Types of intervals: Currently `posterior_interval` only computes central intervals because other types of intervals are rarely useful for the models that **rstanarm** can estimate. Additional possibilities may be provided in future releases as more models become available.

Value

A matrix with two columns and as many rows as model parameters (or the subset of parameters specified by `pars` and/or `regex_pars`). For a given value of `prob`, p , the columns correspond to the lower and upper 100p% interval limits and have the names `100 α /2%` and `100(1 - α /2)%`, where $\alpha = 1 - p$. For example, if `prob=0.9` is specified (a 90% interval), then the column names will be "5%" and "95%", respectively.

References

- Gelman, A. and Carlin, J. (2014). Beyond power calculations: assessing Type S (sign) and Type M (magnitude) errors. *Perspectives on Psychological Science*. 9(6), 641–51.
- Morey, R. D., Hoekstra, R., Rouder, J., Lee, M. D., and Wagenmakers, E. (2016). The fallacy of placing confidence in confidence intervals. *Psychonomic Bulletin & Review*. 23(1), 103–123.

See Also

[confint.stanreg](#), which, for models fit using optimization, can be used to compute traditional confidence intervals.

[predictive_interval](#) for predictive intervals.

Examples

```
if (!exists("example_model")) example(example_model)
posterior_interval(example_model)
posterior_interval(example_model, regex_pars = "herd")
posterior_interval(example_model, pars = "period2", prob = 0.5)
```

posterior_linpred.stanreg

Posterior distribution of the linear predictor

Description

Extract the posterior draws of the linear predictor, possibly transformed by the inverse-link function. This function is occasionally useful, but it should be used sparingly. Inference and model checking should generally be carried out using the posterior predictive distribution (i.e., using [posterior_predict](#)).

Usage

```
## S3 method for class 'stanreg'
posterior_linpred(object, transform = FALSE,
  newdata = NULL, draws = NULL, re.form = NULL, offset = NULL,
  XZ = FALSE, ...)
```

Arguments

object	A fitted model object returned by one of the rstanarm modeling functions. See stanreg-objects .
transform	Should the linear predictor be transformed using the inverse-link function? The default is FALSE, in which case the untransformed linear predictor is returned.
newdata, draws, re.form, offset	Same as for posterior_predict .
XZ	If TRUE then instead of computing the linear predictor the design matrix X (or cbind(X,Z) for models with group-specific terms) constructed from newdata is returned. The default is FALSE.
...	Currently ignored.

Value

The default is to return a `draws by nrow(newdata)` matrix of simulations from the posterior distribution of the (possibly transformed) linear predictor. The exception is if the argument `XZ` is set to `TRUE` (see the `XZ` argument description above).

Note

For models estimated with `stan_clogit`, the number of successes per stratum is ostensibly fixed by the research design. Thus, when calling `posterior_linpred` with new data and `transform = TRUE`, the `data.frame` passed to the `newdata` argument must contain an outcome variable and a stratifying factor, both with the same name as in the original `data.frame`. Then, the probabilities will condition on this outcome in the new data.

See Also

`posterior_predict` to draw from the posterior predictive distribution of the outcome, which is typically preferable.

Examples

```
if (!exists("example_model")) example(example_model)
print(family(example_model))

# linear predictor on log-odds scale
linpred <- posterior_linpred(example_model)
colMeans(linpred)

# probabilities
probs <- posterior_linpred(example_model, transform = TRUE)
colMeans(probs)

# not conditioning on any group-level parameters
probs2 <- posterior_linpred(example_model, transform = TRUE, re.form = NA)
apply(probs2, 2, median)
```

posterior_predict.stanreg

Draw from posterior predictive distribution

Description

The posterior predictive distribution is the distribution of the outcome implied by the model after using the observed data to update our beliefs about the unknown parameters in the model. Simulating data from the posterior predictive distribution using the observed predictors is useful for checking the fit of the model. Drawing from the posterior predictive distribution at interesting values of the predictors also lets us visualize how a manipulation of a predictor affects (a function of) the outcome(s). With new observations of predictor variables we can use the posterior predictive distribution to generate predicted outcomes.

Usage

```
## S3 method for class 'stanreg'
posterior_predict(object, newdata = NULL,
  draws = NULL, re.form = NULL, fun = NULL, seed = NULL,
  offset = NULL, ...)

## S3 method for class 'stanmvreg'
posterior_predict(object, m = 1, newdata = NULL,
  draws = NULL, re.form = NULL, fun = NULL, seed = NULL, ...)
```

Arguments

object	A fitted model object returned by one of the rstanarm modeling functions. See stanreg-objects .
newdata	Optionally, a data frame in which to look for variables with which to predict. If omitted, the model matrix is used. If newdata is provided and any variables were transformed (e.g. rescaled) in the data used to fit the model, then these variables must also be transformed in newdata. This only applies if variables were transformed before passing the data to one of the modeling functions and <i>not</i> if transformations were specified inside the model formula. Also see the Note section below for a note about using the newdata argument with with binomial models.
draws	An integer indicating the number of draws to return. The default and maximum number of draws is the size of the posterior sample.
re.form	If object contains group-level parameters, a formula indicating which group-level parameters to condition on when making predictions. re.form is specified in the same form as for predict.merMod . The default, NULL, indicates that all estimated group-level parameters are conditioned on. To refrain from conditioning on any group-level parameters, specify NA or ~0. The newdata argument may include new <i>levels</i> of the grouping factors that were specified when the model was estimated, in which case the resulting posterior predictions marginalize over the relevant variables.
fun	An optional function to apply to the results. fun is found by a call to match.fun and so can be specified as a function object, a string naming a function, etc.
seed	An optional seed to use.
offset	A vector of offsets. Only required if newdata is specified and an offset argument was specified when fitting the model.
...	For stanmvreg objects, argument m can be specified indicating the submodel for which you wish to obtain predictions.
m	Integer specifying the number or name of the submodel

Value

A draws by nrow(newdata) matrix of simulations from the posterior predictive distribution. Each row of the matrix is a vector of predictions generated using a single draw of the model parameters from the posterior distribution. The returned matrix will also have class "ppd" to indicate it contains draws from the posterior predictive distribution.

Note

For binomial models with a number of trials greater than one (i.e., not Bernoulli models), if `newdata` is specified then it must include all variables needed for computing the number of binomial trials to use for the predictions. For example if the left-hand side of the model formula is `cbind(successes, failures)` then both `successes` and `failures` must be in `newdata`. The particular values of `successes` and `failures` in `newdata` do not matter so long as their sum is the desired number of trials. If the left-hand side of the model formula were `cbind(successes, trials - successes)` then both `trials` and `successes` would need to be in `newdata`, probably with `successes` set to 0 and `trials` specifying the number of trials. See the `Examples` section below and the *How to Use the rstanarm Package* for examples.

For models estimated with `stan_clogit`, the number of successes per stratum is ostensibly fixed by the research design. Thus, when doing posterior prediction with new data, the `data.frame` passed to the `newdata` argument must contain an outcome variable and a stratifying factor, both with the same name as in the original `data.frame`. Then, the posterior predictions will condition on this outcome in the new data.

See Also

[pp_check](#) for graphical posterior predictive checks. Examples of posterior predictive checking can also be found in the **rstanarm** vignettes and demos.

[predictive_error](#) and [predictive_interval](#).

Examples

```
if (!exists("example_model")) example(example_model)
yrep <- posterior_predict(example_model)
table(yrep)

# Using newdata
counts <- c(18,17,15,20,10,20,25,13,12)
outcome <- gl(3,1,9)
treatment <- gl(3,3)
fit3 <- stan_glm(counts ~ outcome + treatment, family = poisson(link="log"),
  prior = normal(0, 1), prior_intercept = normal(0, 5))
nd <- data.frame(treatment = factor(rep(1,3)), outcome = factor(1:3))
ytilde <- posterior_predict(fit3, nd, draws = 500)
print(dim(ytilde)) # 500 by 3 matrix (draws by nrow(nd))
ytilde <- data.frame(count = c(ytilde),
  outcome = rep(nd$outcome, each = 500))
ggplot2::ggplot(ytilde, ggplot2::aes(x=outcome, y=count)) +
  ggplot2::geom_boxplot() +
  ggplot2::ylab("predicted count")

# Using newdata with a binomial model.
# example_model is binomial so we need to set
# the number of trials to use for prediction.
# This could be a different number for each
# row of newdata or the same for all rows.
```

```
# Here we'll use the same value for all.
nd <- lme4::cbpp
print(formula(example_model)) # cbind(incidence, size - incidence) ~ ...
nd$size <- max(nd$size) + 1L # number of trials
nd$incidence <- 0 # set to 0 so size - incidence = number of trials
ytilde <- posterior_predict(example_model, newdata = nd)

# Using fun argument to transform predictions
mtcars2 <- mtcars
mtcars2$log_mpg <- log(mtcars2$mpg)
fit <- stan_glm(log_mpg ~ wt, data = mtcars2)
ytilde <- posterior_predict(fit, fun = exp)
```

posterior_survfit *Estimate subject-specific or standardised survival probabilities*

Description

This function allows us to generate estimated survival probabilities based on draws from the posterior predictive distribution. By default the survival probabilities are conditional on an individual's group-specific coefficients (i.e. their individual-level random effects). If prediction data is provided via the `newdataLong` and `newdataEvent` arguments, then the default behaviour is to sample new group-specific coefficients for the individuals in the new data using a Monte Carlo scheme that conditions on their longitudinal outcome data provided in `newdataLong` (sometimes referred to as "dynamic predictions", see Rizopoulos (2011)). This default behaviour can be stopped by specifying `dynamic = FALSE`, in which case the predicted survival probabilities will be marginalised over the distribution of the group-specific coefficients. This has the benefit that the user does not need to provide longitudinal outcome measurements for the new individuals, however, it does mean that the predictions will incorporate all the uncertainty associated with between-individual variation, since the predictions aren't conditional on any observed data for the individual. In addition, by default, the predicted subject-specific survival probabilities are conditional on observed values of the fixed effect covariates (ie, the predictions will be obtained using either the design matrices used in the original `stan_jm` model call, or using the covariate values provided in the `newdataLong` and `newdataEvent` arguments). However, if you wish to average over the observed distribution of the fixed effect covariates then this is possible – such predictions are sometimes referred to as standardised survival probabilities – see the `standardise` argument below.

Usage

```
posterior_survfit(object, newdataLong = NULL, newdataEvent = NULL,
  extrapolate = TRUE, control = list(), condition = NULL,
  last_time = NULL, prob = 0.95, ids, times = NULL,
  standardise = FALSE, dynamic = TRUE, scale = 1.5, draws = NULL,
  seed = NULL, ...)
```

Arguments

- object** A fitted model object returned by the `stan_jm` modelling function. See [stanreg-objects](#).
- newdataLong, newdataEvent** Optionally, a data frame (or in the case of `newdataLong` this can be a list of data frames) in which to look for variables with which to predict. If omitted, the model matrices are used. If new data is provided, then it should also contain the longitudinal outcome data on which to condition when drawing the new group-specific coefficients for individuals in the new data. Note that there is only allowed to be one row of data for each individual in `newdataEvent`, that is, time-varying covariates are not allowed in the prediction data for the event submodel. Also, `newdataEvent` can optionally include a variable with information about the last known survival time for the new individuals – see the description for the `last_time` argument below – however also note that when generating the survival probabilities it is of course assumed that all individuals in `newdataEvent` have not yet experienced the event (that is, any variable in `newdataEvent` that corresponds to the event indicator will be ignored).
- extrapolate** A logical specifying whether to extrapolate the estimated survival probabilities beyond the times specified in the `times` argument. If `TRUE` then the extrapolation can be further controlled using the `control` argument.
- control** A named list with parameters controlling extrapolation of the estimated survival function when `extrapolate = TRUE`. The list can contain one or more of the following named elements:
- `epoints` a positive integer specifying the number of discrete time points at which to calculate the forecasted survival probabilities. The default is 10.
 - `edist` a positive scalar specifying the amount of time across which to forecast the estimated survival function, represented in units of the time variable `time_var` (from fitting the model). The default is to extrapolate between the times specified in the `times` argument and the maximum event or censoring time in the original data. If `edist` leads to times that are beyond the maximum event or censoring time in the original data then the estimated survival probabilities will be truncated at that point, since the estimate for the baseline hazard is not available beyond that time.
- condition** A logical specifying whether the estimated subject-specific survival probabilities at time `t` should be conditioned on survival up to a fixed time point `u`. The default is for `condition` to be set to `TRUE`, unless standardised survival probabilities have been requested (by specifying `standardise = TRUE`), in which case `condition` must (and will) be set to `FALSE`. When conditional survival probabilities are requested, the fixed time point `u` will be either: (i) the value specified via the `last_time` argument; or if the `last_time` argument is `NULL` then the latest observation time for each individual (taken to be the value in the `times` argument if `newdataEvent` is specified, or the observed event or censoring time if `newdataEvent` is `NULL`).
- last_time** A scalar, character string, or `NULL`. This argument specifies the last known survival time for each individual when conditional predictions are being obtained. If `newdataEvent` is provided and conditional survival predictions are being obtained, then the `last_time` argument can be one of the following: (i) a scalar,

this will use the same last time for each individual in `newdataEvent`; (ii) a character string, naming a column in `newdataEvent` in which to look for the last time for each individual; (iii) `NULL`, in which case the default is to use the time of the latest longitudinal observation in `newdataLong`. If `newdataEvent` is `NULL` then the `last_time` argument cannot be specified directly; instead it will be set equal to the event or censoring time for each individual in the dataset that was used to estimate the model. If standardised survival probabilities are requested (i.e. `standardise = TRUE`) then conditional survival probabilities are not allowed and therefore the `last_time` argument is ignored.

<code>prob</code>	A scalar between 0 and 1 specifying the width to use for the uncertainty interval (sometimes called credible interval) for the predictions. For example <code>prob = 0.95</code> (the default) means that the 2.5th and 97.5th percentiles will be provided.
<code>ids</code>	An optional vector specifying a subset of IDs for whom the predictions should be obtained. The default is to predict for all individuals who were used in estimating the model or, if <code>newdataLong</code> and <code>newdataEvent</code> are specified, then all individuals contained in the new data.
<code>times</code>	A scalar, a character string, or <code>NULL</code> . Specifies the times at which the estimated survival probabilities should be calculated. It can be either: (i) <code>NULL</code> , in which case it will default to the last known survival time for each individual, as determined by the <code>last_time</code> argument; (ii) a scalar, specifying a time to estimate the survival probability for each of the individuals; or (iii) if <code>newdataEvent</code> is provided, it can be the name of a variable in <code>newdataEvent</code> that indicates the time at which the survival probabilities should be calculated for each individual.
<code>standardise</code>	A logical specifying whether the estimated subject-specific survival probabilities should be averaged across all individuals for whom the subject-specific predictions are being obtained. This can be used to average over the covariate and random effects distributions of the individuals used in estimating the model, or the individuals included in the <code>newdata</code> arguments. This approach of averaging across the observed distribution of the covariates is sometimes referred to as a "standardised" survival curve. If <code>standardise = TRUE</code> , then the <code>times</code> argument must be specified and it must be constant across individuals, that is, the survival probabilities must be calculated at the same time for all individuals.
<code>dynamic</code>	A logical that is only relevant if new data is provided via the <code>newdataLong</code> and <code>newdataEvent</code> arguments. If <code>dynamic = TRUE</code> , then new group-specific parameters are drawn for the individuals in the new data, conditional on their longitudinal biomarker data contained in <code>newdataLong</code> . These group-specific parameters are then used to generate individual-specific survival probabilities for these individuals. These are often referred to as "dynamic predictions" in the joint modelling context, because the predictions can be updated each time additional longitudinal biomarker data is collected on the individual. On the other hand, if <code>dynamic = FALSE</code> then the survival probabilities will just be marginalised over the distribution of the group-specific coefficients; this will mean that the predictions will incorporate all uncertainty due to between-individual variation so there will likely be very wide credible intervals on the predicted survival probabilities.
<code>scale</code>	A scalar, specifying how much to multiply the asymptotic variance-covariance

	matrix for the random effects by, which is then used as the "width" (ie. variance-covariance matrix) of the multivariate Student-t proposal distribution in the Metropolis-Hastings algorithm. This is only relevant when <code>newdataEvent</code> is supplied and <code>dynamic = TRUE</code> , in which case new random effects are simulated for the individuals in the new data using the Metropolis-Hastings algorithm.
<code>draws</code>	An integer indicating the number of MCMC draws to return. The default is to set the number of draws equal to 200, or equal to the size of the posterior sample if that is less than 200.
<code>seed</code>	An optional seed to use.
<code>...</code>	Currently unused.

Value

A data frame of class `survfit.stanjm`. The data frame includes columns for each of the following: (i) the median of the posterior predictions of the estimated survival probabilities (`survpred`); (ii) each of the lower and upper limits of the corresponding uncertainty interval for the estimated survival probabilities (`ci_lb` and `ci_ub`); (iii) a subject identifier (`id_var`), unless standardised survival probabilities were estimated; (iv) the time that the estimated survival probability is calculated for (`time_var`). The returned object also includes a number of additional attributes.

Note

Note that if any variables were transformed (e.g. rescaled) in the data used to fit the model, then these variables must also be transformed in `newdataLong` and `newdataEvent`. This only applies if variables were transformed before passing the data to one of the modeling functions and *not* if transformations were specified inside the model formula.

References

Rizopoulos, D. (2011). Dynamic predictions and prospective accuracy in joint models for longitudinal and time-to-event data. *Biometrics* **67**, 819.

See Also

[plot.survfit.stanjm](#) for plotting the estimated survival probabilities, [ps_check](#) for graphical checks of the estimated survival function, and [posterior_traj](#) for estimating the marginal or subject-specific longitudinal trajectories, and [plot_stack_jm](#) for combining plots of the estimated subject-specific longitudinal trajectory and survival function.

Examples

```
# Run example model if not already loaded
if (!exists("example_jm")) example(example_jm)

# Obtain subject-specific survival probabilities for a few
# selected individuals in the estimation dataset who were
# known to survive up until their censoring time. By default
# the posterior_survfit function will estimate the conditional
```

```

# survival probabilities, that is, conditional on having survived
# until the event or censoring time, and then by default will
# extrapolate the survival predictions forward from there.
ps1 <- posterior_survfit(example_jm, ids = c(7,13,15))
# We can plot the estimated survival probabilities using the
# associated plot function
plot(ps1)

# If we wanted to estimate the survival probabilities for the
# same three individuals as the previous example, but this time
# we won't condition on them having survived up until their
# censoring time. Instead, we will estimate their probability
# of having survived between 0 and 5 years given their covariates
# and their estimated random effects.
# The easiest way to achieve the time scale we want (ie, 0 to 5 years)
# is to specify that we want the survival time estimated at time 0
# and then extrapolated forward 5 years. We also specify that we
# do not want to condition on their last known survival time.
ps2 <- posterior_survfit(example_jm, ids = c(7,13,15), times = 0,
  extrapolate = TRUE, condition = FALSE, control = list(edist = 5))

# Instead we may want to estimate subject-specific survival probabilities
# for a set of new individuals. To demonstrate this, we will simply take
# the first two individuals in the estimation dataset, but pass their data
# via the newdata arguments so that posterior_survfit will assume we are
# predicting survival for new individuals and draw new random effects
# under a Monte Carlo scheme (see Rizopoulos (2011)).
ndL <- pbcLong[pbcLong$id %in% c(1,2),]
ndE <- pbcSurv[pbcSurv$id %in% c(1,2),]
ps3 <- posterior_survfit(example_jm,
  newdataLong = ndL, newdataEvent = ndE,
  last_time = "fuptimeYears", seed = 12345)
head(ps3)
# We can then compare the estimated random effects for these
# individuals based on the fitted model and the Monte Carlo scheme
ranef(example_jm)$Long1$id[1:2,,drop=FALSE] # from fitted model
colMeans(attr(ps3, "b_new")) # from Monte Carlo scheme

# Lastly, if we wanted to obtain "standardised" survival probabilities,
# (by averaging over the observed distribution of the fixed effect
# covariates, as well as averaging over the estimated random effects
# for individuals in our estimation sample or new data) then we can
# specify 'standardise = TRUE'. We can then plot the resulting
# standardised survival curve.
ps4 <- posterior_survfit(example_jm, standardise = TRUE,
  times = 0, extrapolate = TRUE)
plot(ps4)

```

Description

This function allows us to generate an estimated longitudinal trajectory (either subject-specific, or by marginalising over the distribution of the group-specific parameters) based on draws from the posterior predictive distribution.

Usage

```
posterior_traj(object, m = 1, newdata = NULL, newdataLong = NULL,
  newdataEvent = NULL, interpolate = TRUE, extrapolate = FALSE,
  control = list(), last_time = NULL, prob = 0.95, ids,
  dynamic = TRUE, scale = 1.5, draws = NULL, seed = NULL,
  return_matrix = FALSE, ...)
```

Arguments

object	A fitted model object returned by the stan_jm modelling function. See stanreg-objects .
m	Integer specifying the number or name of the submodel
newdata	Deprecated: please use newdataLong instead. Optionally, a data frame in which to look for variables with which to predict. If omitted, the model matrix is used. If newdata is provided and any variables were transformed (e.g. rescaled) in the data used to fit the model, then these variables must also be transformed in newdata. This only applies if variables were transformed before passing the data to one of the modeling functions and <i>not</i> if transformations were specified inside the model formula.
newdataLong, newdataEvent	Optionally, a data frame (or in the case of newdataLong this can be a list of data frames) in which to look for variables with which to predict. If omitted, the model matrices are used. If new data is provided, then two options are available. Either one can provide observed covariate and outcome data, collected up to some time t , and use this data to draw new individual-specific coefficients (i.e. individual-level random effects). This is the default behaviour when new data is provided, determined by the argument <code>dynamic = TRUE</code> , and requiring both newdataLong and newdataEvent to be specified. Alternatively, one can specify <code>dynamic = FALSE</code> , and then predict using just covariate data, by marginalising over the distribution of the group-specific coefficients; in this case, only newdataLong needs to be specified and it only needs to be a single data frame with the covariate data for the predictions for the one longitudinal submodel.
interpolate	A logical specifying whether to interpolate the estimated longitudinal trajectory in between the observation times. This can be used to achieve a smooth estimate of the longitudinal trajectory across the entire follow up time. If TRUE then the interpolation can be further controlled using the control argument.
extrapolate	A logical specifying whether to extrapolate the estimated longitudinal trajectory beyond the time of the last known observation time. If TRUE then the extrapolation can be further controlled using the control argument.
control	A named list with parameters controlling the interpolation or extrapolation of the estimated longitudinal trajectory when either <code>interpolate = TRUE</code> or <code>extrapolate = TRUE</code> . The list can contain one or more of the following named

elements:

	<p><code>ipoints</code> a positive integer specifying the number of discrete time points at which to calculate the estimated longitudinal response for <code>interpolate = TRUE</code>. These time points are evenly spaced starting at 0 and ending at the last known observation time for each individual. The last observation time for each individual is taken to be either: the event or censoring time if no new data is provided; the time specified in the "last_time" column if provided in the new data (see Details section below); or the time of the last longitudinal measurement if new data is provided but no "last_time" column is included. The default is 15.</p> <p><code>epoints</code> a positive integer specifying the number of discrete time points at which to calculate the estimated longitudinal response for <code>extrapolate = TRUE</code>. These time points are evenly spaced between the last known observation time for each individual and the extrapolation distance specified using either <code>edist</code> or <code>eprop</code>. The default is 15.</p> <p><code>eprop</code> a positive scalar between 0 and 1 specifying the amount of time across which to extrapolate the longitudinal trajectory, represented as a proportion of the total observed follow up time for each individual. For example specifying <code>eprop = 0.2</code> means that for an individual for whom the latest of their measurement, event or censoring times was 10 years, their estimated longitudinal trajectory will be extrapolated out to 12 years (i.e. $10 + (0.2 * 10)$). The default value is 0.2.</p> <p><code>edist</code> a positive scalar specifying the amount of time across which to extrapolate the longitudinal trajectory for each individual, represented in units of the time variable <code>time_var</code> (from fitting the model). This cannot be specified if <code>eprop</code> is specified.</p>
<code>last_time</code>	<p>A scalar, character string, or NULL. This argument specifies the last known survival time for each individual when conditional predictions are being obtained. If <code>newdataEvent</code> is provided and conditional survival predictions are being obtained, then the <code>last_time</code> argument can be one of the following: (i) a scalar, this will use the same last time for each individual in <code>newdataEvent</code>; (ii) a character string, naming a column in <code>newdataEvent</code> in which to look for the last time for each individual; (iii) NULL, in which case the default is to use the time of the latest longitudinal observation in <code>newdataLong</code>. If <code>newdataEvent</code> is NULL then the <code>last_time</code> argument cannot be specified directly; instead it will be set equal to the event or censoring time for each individual in the dataset that was used to estimate the model. If standardised survival probabilities are requested (i.e. <code>standardise = TRUE</code>) then conditional survival probabilities are not allowed and therefore the <code>last_time</code> argument is ignored.</p>
<code>prob</code>	<p>A scalar between 0 and 1 specifying the width to use for the uncertainty interval (sometimes called credible interval) for the predicted mean response and the prediction interval for the predicted (raw) response. For example <code>prob = 0.95</code> (the default) means that the 2.5th and 97.5th percentiles will be provided. Only relevant when <code>return_matrix</code> is FALSE.</p>
<code>ids</code>	<p>An optional vector specifying a subset of subject IDs for whom the predictions should be obtained. The default is to predict for all individuals who were used in</p>

	estimating the model or, if <code>newdata</code> is specified, then all individuals contained in <code>newdata</code> .
<code>dynamic</code>	A logical that is only relevant if new data is provided via the <code>newdata</code> argument. If <code>dynamic = TRUE</code> , then new group-specific parameters are drawn for the individuals in the new data, conditional on their longitudinal biomarker data contained in <code>newdata</code> . These group-specific parameters are then used to generate individual-specific survival probabilities for these individuals. These are often referred to as "dynamic predictions" in the joint modelling context, because the predictions can be updated each time additional longitudinal biomarker data is collected on the individual. On the other hand, if <code>dynamic = FALSE</code> then the survival probabilities will just be marginalised over the distribution of the group-specific coefficients; this will mean that the predictions will incorporate all uncertainty due to between-individual variation so there will likely be very wide credible intervals on the predicted survival probabilities.
<code>scale</code>	A scalar, specifying how much to multiply the asymptotic variance-covariance matrix for the random effects by, which is then used as the "width" (ie. variance-covariance matrix) of the multivariate Student-t proposal distribution in the Metropolis-Hastings algorithm. This is only relevant when <code>newdataEvent</code> is supplied and <code>dynamic = TRUE</code> , in which case new random effects are simulated for the individuals in the new data using the Metropolis-Hastings algorithm.
<code>draws</code>	An integer indicating the number of MCMC draws to return. The default is to set the number of draws equal to 200, or equal to the size of the posterior sample if that is less than 200.
<code>seed</code>	An optional seed to use.
<code>return_matrix</code>	A logical. If <code>TRUE</code> then a <code>draws</code> by <code>nrow(newdata)</code> matrix is returned which contains all the actual simulations or draws from the posterior predictive distribution. Otherwise if <code>return_matrix</code> is set to <code>FALSE</code> (the default) then a data frame is returned, as described in the Value section below.
<code>...</code>	Other arguments passed to posterior_predict , for example <code>draws</code> , <code>re.form</code> , <code>seed</code> , etc.

Details

The `posterior_traj` function acts as a wrapper to the [posterior_predict](#) function, but allows predictions to be easily generated at time points that are interpolated and/or extrapolated between time zero (baseline) and the last known survival time for the individual, thereby providing predictions that correspond to a smooth estimate of the longitudinal trajectory (useful for the plotting via the associated [plot.predict.stanjm](#) method). In addition it returns a data frame by default, whereas the [posterior_predict](#) function returns a matrix; see the **Value** section below for details. Also, `posterior_traj` allows predictions to only be generated for a subset of individuals, via the `ids` argument.

Value

When `return_matrix = FALSE`, a data frame of class `predict.stanjm`. The data frame includes a column for the median of the posterior predictions of the mean longitudinal response (`yfit`), a column for each of the lower and upper limits of the uncertainty interval corresponding to the

posterior predictions of the mean longitudinal response (`ci_lb` and `ci_ub`), and a column for each of the lower and upper limits of the prediction interval corresponding to the posterior predictions of the (raw) longitudinal response. The data frame also includes columns for the subject ID variable, and each of the predictor variables. The returned object also includes a number of attributes.

When `return_matrix = TRUE`, the returned object is the same as that described for [posterior_predict](#).

See Also

[plot.predict.stanjm](#), [posterior_predict](#), [posterior_survfit](#)

Examples

```
# Run example model if not already loaded
if (!exists("example_jm")) example(example_jm)

# Obtain subject-specific predictions for all individuals
# in the estimation dataset
pt1 <- posterior_traj(example_jm, interpolate = FALSE, extrapolate = FALSE)
head(pt1)

# Obtain subject-specific predictions only for a few selected individuals
pt2 <- posterior_traj(example_jm, ids = c(1,3,8))

# If we wanted to obtain subject-specific predictions in order to plot the
# longitudinal trajectories, then we might want to ensure a full trajectory
# is obtained by interpolating and extrapolating time. We can then use the
# generic plot function to plot the subject-specific predicted trajectories
# for the first three individuals. Interpolation and extrapolation is
# carried out by default.
pt3 <- posterior_traj(example_jm)
head(pt3) # predictions at additional time points compared with pt1
plot(pt3, ids = 1:3)

# If we wanted to extrapolate further in time, but decrease the number of
# discrete time points at which we obtain predictions for each individual,
# then we could specify a named list in the 'control' argument
pt4 <- posterior_traj(example_jm, control = list(ipoints = 10, epoints = 10, eprop = 0.5))

# If we have prediction data for a new individual, and we want to
# estimate the longitudinal trajectory for that individual conditional
# on this new data (perhaps extrapolating forward from our last
# longitudinal measurement) then we can do that. It requires drawing
# new individual-specific parameters, based on the full likelihood,
# so we must supply new data for both the longitudinal and event
# submodels. These are sometimes known as dynamic predictions.
ndL <- pbclong[pbclong$id == 8, , drop = FALSE]
ndE <- pbcSurv[pbcSurv$id == 8, , drop = FALSE]
ndL$id <- "new_subject" # new id can't match one used in training data
ndE$id <- "new_subject"
pt5 <- posterior_traj(example_jm,
                      newdataLong = ndL,
```

```

newdataEvent = ndE)

# By default it is assumed that the last known survival time for
# the individual is the time of their last biomarker measurement,
# but if we know they survived to some later time then we can
# condition on that information using the last_time argument
pt6 <- posterior_traj(example_jm,
                      newdataLong = ndL,
                      newdataEvent = ndE,
                      last_time = "fuptimeYears")

# Alternatively we may want to estimate the marginal longitudinal
# trajectory for a given set of covariates. To do this, we can pass
# the desired covariate values in a new data frame (however the only
# covariate in our fitted model was the time variable, year). To make sure
# that we marginalise over the random effects, we need to specify an ID value
# which does not correspond to any of the individuals who were used in the
# model estimation and specify the argument dynamic=FALSE.
# The marginal prediction is obtained by generating subject-specific
# predictions using a series of random draws from the random
# effects distribution, and then integrating (ie, averaging) over these.
# Our marginal prediction will therefore capture the between-individual
# variation associated with the random effects.
nd <- data.frame(id = rep("new1", 11), year = (0:10 / 2))
pt7 <- posterior_traj(example_jm, newdataLong = nd, dynamic = FALSE)
head(pt7) # note the greater width of the uncertainty interval compared
          # with the subject-specific predictions in pt1, pt2, etc

# Alternatively, we could have estimated the "marginal" trajectory by
# ignoring the random effects (ie, assuming the random effects were set
# to zero). This will generate a predicted longitudinal trajectory only
# based on the fixed effect component of the model. In essence, for a
# linear mixed effects model (ie, a model that uses an identity link
# function), we should obtain a similar point estimate ("yfit") to the
# estimates obtained in pt5 (since the mean of the estimated random effects
# distribution will be approximately 0). However, it is important to note that
# the uncertainty interval will be much more narrow, since it completely
# ignores the between-individual variability captured by the random effects.
# Further, if the model uses a non-identity link function, then the point
# estimate ("yfit") obtained only using the fixed effect component of the
# model will actually provide a biased estimate of the marginal prediction.
# Nonetheless, to demonstrate how we can obtain the predictions only using
# the fixed effect component of the model, we simply specify 're.form = NA'.
# (We will use the same covariate values as used in the prediction for
# example for pt5).
pt8 <- posterior_traj(example_jm, newdataLong = nd, dynamic = FALSE,
                      re.form = NA)
head(pt8) # note the much narrower ci, compared with pt5

```

 posterior_vs_prior *Juxtapose prior and posterior*

Description

Plot medians and central intervals comparing parameter draws from the prior and posterior distributions. If the plotted priors look different than the priors you think you specified it is likely either because of internal rescaling or the use of the `QR` argument (see the documentation for the [prior_summary](#) method for details on these special cases).

Usage

```
posterior_vs_prior(object, ...)

## S3 method for class 'stanreg'
posterior_vs_prior(object, pars = NULL,
  regex_pars = NULL, prob = 0.9, color_by = c("parameter", "vs",
  "none"), group_by_parameter = FALSE, facet_args = list(), ...)
```

Arguments

object	A fitted model object returned by one of the rstanarm modeling functions. See stanreg-objects .
...	The S3 generic uses ... to pass arguments to any defined methods. For the method for stanreg objects, ... is for arguments (other than color) passed to geom_pointrange to control the appearance of the plotted intervals.
pars	<p>An optional character vector specifying a subset of parameters to display. Parameters can be specified by name or several shortcuts can be used. Using <code>pars="beta"</code> will restrict the displayed parameters to only the regression coefficients (without the intercept). <code>"alpha"</code> can also be used as a shortcut for <code>"(Intercept)"</code>. If the model has varying intercepts and/or slopes they can be selected using <code>pars = "varying"</code>.</p> <p>In addition, for stanmvreg objects there are some additional shortcuts available. Using <code>pars = "long"</code> will display the parameter estimates for the longitudinal submodels only (excluding group-specific parameters, but including auxiliary parameters). Using <code>pars = "event"</code> will display the parameter estimates for the event submodel only, including any association parameters. Using <code>pars = "assoc"</code> will display only the association parameters. Using <code>pars = "fixef"</code> will display all fixed effects, but not the random effects or the auxiliary parameters. <code>pars</code> and <code>regex_pars</code> are set to <code>NULL</code> then all fixed effect regression coefficients are selected, as well as any auxiliary parameters and the log posterior.</p> <p>If <code>pars</code> is <code>NULL</code> all parameters are selected for a stanreg object, while for a stanmvreg object all fixed effect regression coefficients are selected as well as any auxiliary parameters and the log posterior. See Examples.</p>

regex_pars	An optional character vector of regular expressions to use for parameter selection. regex_pars can be used in place of pars or in addition to pars. Currently, all functions that accept a regex_pars argument ignore it for models fit using optimization.
prob	A number $p \in (0, 1)$ indicating the desired posterior probability mass to include in the (central posterior) interval estimates displayed in the plot. The default is 0.9.
color_by	How should the estimates be colored? Use "parameter" to color by parameter name, "vs" to color the prior one color and the posterior another, and "none" to use no color. Except when color_by="none", a variable is mapped to the color aesthetic and it is therefore also possible to change the default colors by adding one of the various discrete color scales available in ggplot2 (scale_color_manual , scale_color_brewer , etc.). See Examples.
group_by_parameter	Should estimates be grouped together by parameter (TRUE) or by posterior and prior (FALSE, the default)?
facet_args	A named list of arguments passed to facet_wrap (other than the facets argument), e.g., nrow or ncol to change the layout, scales to allow axis scales to vary across facets, etc. See Examples.

Value

A ggplot object that can be further customized using the [ggplot2](#) package.

References

Gabry, J., Simpson, D., Vehtari, A., Betancourt, M., and Gelman, A. (2018). Visualization in Bayesian workflow. *Journal of the Royal Statistical Society Series A*, accepted for publication. arXiv preprint: <http://arxiv.org/abs/1709.01449>.

Examples

```
## Not run:
if (!exists("example_model")) example(example_model)
# display non-varying (i.e. not group-level) coefficients
posterior_vs_prior(example_model, pars = "beta")

# show group-level (varying) parameters and group by parameter
posterior_vs_prior(example_model, pars = "varying",
                    group_by_parameter = TRUE, color_by = "vs")

# group by parameter and allow axis scales to vary across facets
posterior_vs_prior(example_model, regex_pars = "period",
                    group_by_parameter = TRUE, color_by = "none",
                    facet_args = list(scales = "free"))

# assign to object and customize with functions from ggplot2
(gg <- posterior_vs_prior(example_model, pars = c("beta", "varying"), prob = 0.8))
```

```

gg +
  ggplot2::geom_hline(yintercept = 0, size = 0.3, linetype = 3) +
  ggplot2::coord_flip() +
  ggplot2::ggtitle("Comparing the prior and posterior")

# compare very wide and very narrow priors using roaches example
# (see help(roaches, "rstanarm") for info on the dataset)
roaches$roach100 <- roaches$roach1 / 100
wide_prior <- normal(0, 10)
narrow_prior <- normal(0, 0.1)
fit_pois_wide_prior <- stan_glm(y ~ treatment + roach100 + senior,
                              offset = log(exposure2),
                              family = "poisson", data = roaches,
                              prior = wide_prior)
posterior_vs_prior(fit_pois_wide_prior, pars = "beta", prob = 0.5,
                   group_by_parameter = TRUE, color_by = "vs",
                   facet_args = list(scales = "free"))

fit_pois_narrow_prior <- update(fit_pois_wide_prior, prior = narrow_prior)
posterior_vs_prior(fit_pois_narrow_prior, pars = "beta", prob = 0.5,
                   group_by_parameter = TRUE, color_by = "vs",
                   facet_args = list(scales = "free"))

# look at cutpoints for ordinal model
fit_polr <- stan_polr(tobgp ~ agegp, data = esoph, method = "probit",
                    prior = R2(0.2, "mean"), init_r = 0.1)
(gg_polr <- posterior_vs_prior(fit_polr, regex_pars = "\\|", color_by = "vs",
                              group_by_parameter = TRUE))

# flip the x and y axes
gg_polr + ggplot2::coord_flip()

## End(Not run)

```

pp_check.stanreg

Graphical posterior predictive checks

Description

Interface to the [PPC](#) (posterior predictive checking) module in the [bayesplot](#) package, providing various plots comparing the observed outcome variable y to simulated datasets y^{rep} from the posterior predictive distribution. The `pp_check` method for [stanreg-objects](#) prepares the arguments required for the specified [bayesplot](#) PPC plotting function and then calls that function. It is also straightforward to use the functions from the [bayesplot](#) package directly rather than via the `pp_check` method. Examples of both are given below.

Usage

```
## S3 method for class 'stanreg'
```

```
pp_check(object, plotfun = "dens_overlay",
         nreps = NULL, seed = NULL, ...)
```

Arguments

object	A fitted model object returned by one of the rstanarm modeling functions. See stanreg-objects .
plotfun	A character string naming the bayesplot PPC function to use. The default is to call ppc_dens_overlay . plotfun can be specified either as the full name of a bayesplot plotting function (e.g. "ppc_hist") or can be abbreviated to the part of the name following the "ppc_" prefix (e.g. "hist"). To get the names of all available PPC functions see available_ppc .
nreps	The number of y^{rep} datasets to generate from the posterior predictive distribution and show in the plots. The default depends on plotfun. For functions that plot each yrep dataset separately (e.g. ppc_hist), nreps defaults to a small value to make the plots readable. For functions that overlay many yrep datasets (e.g., ppc_dens_overlay) a larger number is used by default, and for other functions (e.g. ppc_stat) the default is to set nreps equal to the posterior sample size.
seed	An optional seed to pass to posterior_predict .
...	Additional arguments passed to the bayesplot function called. For many plotting functions ... is optional, however for functions that require a group or x argument, these arguments should be specified in ... If specifying group and/or x, they can be provided as either strings naming variables (in which case they are searched for in the model frame) or as vectors containing the actual values of the variables. See the Examples section, below.

Value

pp_check returns a ggplot object that can be further customized using the **ggplot2** package.

Note

For binomial data, plots of y and y^{rep} show the proportion of 'successes' rather than the raw count. Also for binomial models see [ppc_error_binned](#) for binned residual plots.

References

- Gelman, A., Carlin, J. B., Stern, H. S., Dunson, D. B., Vehtari, A., and Rubin, D. B. (2013). *Bayesian Data Analysis*. Chapman & Hall/CRC Press, London, third edition. (Ch. 6)
- Gabry, J., Simpson, D., Vehtari, A., Betancourt, M., and Gelman, A. (2018). Visualization in Bayesian workflow. *Journal of the Royal Statistical Society Series A*, accepted for publication. arXiv preprint: <http://arxiv.org/abs/1709.01449>.

See Also

- The vignettes in the **bayesplot** package for many examples. Examples of posterior predictive checks can also be found in the **rstanarm** vignettes and demos.

- [PPC-overview \(bayesplot\)](#) for links to the documentation for all the available plotting functions.
- [posterior_predict](#) for drawing from the posterior predictive distribution.
- [color_scheme_set](#) to change the color scheme of the plots.

Examples

```
fit <- stan_glmmer(mpg ~ wt + am + (1|cyl), data = mtcars,
                  iter = 400, chains = 2) # just to keep example quick

# Compare distribution of y to distributions of multiple yrep datasets
pp_check(fit)
pp_check(fit, plotfun = "boxplot", nreps = 10, notch = FALSE)
pp_check(fit, plotfun = "hist", nreps = 3)

# Same plot (up to RNG noise) using bayesplot package directly
bayesplot::ppc_hist(y = mtcars$mpg, yrep = posterior_predict(fit, draws = 3))

# Check histograms of test statistics by level of grouping variable 'cyl'
pp_check(fit, plotfun = "stat_grouped", stat = "median", group = "cyl")

# Defining a custom test statistic
q25 <- function(y) quantile(y, probs = 0.25)
pp_check(fit, plotfun = "stat_grouped", stat = "q25", group = "cyl")

# Scatterplot of two test statistics
pp_check(fit, plotfun = "stat_2d", stat = c("mean", "sd"))

# Scatterplot of y vs. average yrep
pp_check(fit, plotfun = "scatter_avg") # y vs. average yrep
# Same plot (up to RNG noise) using bayesplot package directly
bayesplot::ppc_scatter_avg(y = mtcars$mpg, yrep = posterior_predict(fit))

# Scatterplots of y vs. several individual yrep datasets
pp_check(fit, plotfun = "scatter", nreps = 3)

# Same plot (up to RNG noise) using bayesplot package directly
bayesplot::ppc_scatter(y = mtcars$mpg, yrep = posterior_predict(fit, draws = 3))

# yrep intervals with y points overlaid
# by default 1:length(y) used on x-axis but can also specify an x variable
pp_check(fit, plotfun = "intervals")
pp_check(fit, plotfun = "intervals", x = "wt") + ggplot2::xlab("wt")

# Same plot (up to RNG noise) using bayesplot package directly
bayesplot::ppc_intervals(y = mtcars$mpg, yrep = posterior_predict(fit),
                        x = mtcars$wt) + ggplot2::xlab("wt")

# predictive errors
pp_check(fit, plotfun = "error_hist", nreps = 6)
pp_check(fit, plotfun = "error_scatter_avg_vs_x", x = "wt") +
```

```

ggplot2::xlab("wt")

# Example of a PPC for ordinal models (stan_polr)
fit2 <- stan_polr(tobgp ~ agegp, data = esoph, method = "probit",
  prior = R2(0.2, "mean"), init_r = 0.1)
pp_check(fit2, plotfun = "bars", nreps = 500, prob = 0.5)
pp_check(fit2, plotfun = "bars_grouped", group = esoph$agegp,
  nreps = 500, prob = 0.5)

```

pp_validate

Model validation via simulation

Description

The `pp_validate` function is based on the methods described in Cook, Gelman, and Rubin (2006) for validating software developed to fit particular Bayesian models. Here we take the perspective that models themselves are software and thus it is useful to apply this validation approach to individual models.

Usage

```
pp_validate(object, nreps = 20, seed = 12345, ...)
```

Arguments

<code>object</code>	A fitted model object returned by one of the rstanarm modeling functions. See stanreg-objects .
<code>nreps</code>	The number of replications to be performed. <code>nreps</code> must be sufficiently large so that the statistics described below in Details are meaningful. Depending on the model and the size of the data, running <code>pp_validate</code> may be slow. See also the Note section below for advice on avoiding numerical issues.
<code>seed</code>	A seed passed to Stan to use when refitting the model.
<code>...</code>	Currently ignored.

Details

We repeat `nreps` times the process of simulating parameters and data from the model and refitting the model to this simulated data. For each of the `nreps` replications we do the following:

1. Refit the model but *without* conditioning on the data (setting `prior_PD=TRUE`), obtaining draws θ^{true} from the *prior* distribution of the model parameters.
2. Given θ^{true} , simulate data y^* from the *prior* predictive distribution (calling `posterior_predict` on the fitted model object obtained in step 1).
3. Fit the model to the simulated outcome y^* , obtaining parameters θ^{post} .

For any individual parameter, the quantile of the "true" parameter value with respect to its posterior distribution *should* be uniformly distributed. The validation procedure entails looking for deviations from uniformity by computing statistics for a test that the quantiles are uniformly distributed. The absolute values of the computed test statistics are plotted for batches of parameters (e.g., non-varying coefficients are grouped into a batch called "beta", parameters that vary by group level are in batches named for the grouping variable, etc.). See Cook, Gelman, and Rubin (2006) for more details on the validation procedure.

Value

A `ggplot` object that can be further customized using the `ggplot2` package.

Note

In order to make it through `nreps` replications without running into numerical difficulties you may have to restrict the range for randomly generating initial values for parameters when you fit the *original* model. With any of `rstanarm`'s modeling functions this can be done by specifying the optional argument `init_r` as some number less than the default of 2.

References

Cook, S., Gelman, A., and Rubin, D. (2006). Validation of software for Bayesian models using posterior quantiles. *Journal of Computational and Graphical Statistics*. 15(3), 675–692.

See Also

[pp_check](#) for graphical posterior predictive checks and [posterior_predict](#) to draw from the posterior predictive distribution.

[color_scheme_set](#) to change the color scheme of the plot.

Examples

```
## Not run:  
if (!exists("example_model")) example(example_model)  
try(pp_validate(example_model)) # fails with default seed / priors  
  
## End(Not run)
```

predict.stanreg

Predict method for stanreg objects

Description

This method is primarily intended to be used only for models fit using optimization. For models fit using MCMC or one of the variational approximations, see [posterior_predict](#).

Usage

```
## S3 method for class 'stanreg'
predict(object, ..., newdata = NULL, type = c("link",
      "response"), se.fit = FALSE)
```

Arguments

object	A fitted model object returned by one of the rstanarm modeling functions. See stanreg-objects .
...	Ignored.
newdata	Optionally, a data frame in which to look for variables with which to predict. If omitted, the model matrix is used.
type	The type of prediction. The default 'link' is on the scale of the linear predictors; the alternative 'response' is on the scale of the response variable.
se.fit	A logical scalar indicating if standard errors should be returned. The default is FALSE.

Value

A vector if `se.fit` is FALSE and a list if `se.fit` is TRUE.

See Also

[posterior_predict](#)

predictive_error.stanreg

In-sample or out-of-sample predictive errors

Description

This is a convenience function for computing $y - y^{rep}$ (in-sample, for observed y) or $y - \tilde{y}$ (out-of-sample, for new or held-out y). The method for stanreg objects calls [posterior_predict](#) internally, whereas the method for objects with class "ppd" accepts the matrix returned by [posterior_predict](#) as input and can be used to avoid multiple calls to [posterior_predict](#).

Usage

```
## S3 method for class 'stanreg'
predictive_error(object, newdata = NULL,
  draws = NULL, re.form = NULL, seed = NULL, offset = NULL, ...)

## S3 method for class 'ppd'
predictive_error(object, y, ...)
```


Arguments

object	Either a fitted model object returned by one of the rstanarm modeling functions (a stanreg object) or, for the "ppd" method, a matrix of draws from the posterior predictive distribution returned by posterior_predict .
newdata, draws, seed, offset, re.form	Optional arguments passed to posterior_predict . For binomial models, please see the Note section below if newdata will be specified.
...	Currently ignored.
y	For the "ppd" method only, a vector of <i>y</i> values the same length as the number of columns in the matrix used as object. The method for stanreg objects takes <i>y</i> directly from the fitted model object.

Value

A draws by `nrow(newdata)` matrix. If `newdata` is not specified then it will be draws by `nobs(object)`.

Note

The **Note** section in [posterior_predict](#) about `newdata` for binomial models also applies for `predictive_error`, with one important difference. For `posterior_predict` if the left-hand side of the model formula is `cbind(successes, failures)` then the particular values of `successes` and `failures` in `newdata` don't matter, only that they add to the desired number of trials. **This is not the case for** `predictive_error`. For `predictive_error` the particular value of `successes` matters because it is used as *y* when computing the error.

See Also

[posterior_predict](#) to draw from the posterior predictive distribution without computing predictive errors.

Examples

```
if (!exists("example_model")) example(example_model)
err1 <- predictive_error(example_model, draws = 50)
hist(err1)

# Using newdata with a binomial model
formula(example_model)
nd <- data.frame(
  size = c(10, 20),
  incidence = c(5, 10),
  period = factor(c(1,2)),
  herd = c(1, 15)
)
err2 <- predictive_error(example_model, newdata = nd, draws = 10, seed = 1234)

# stanreg vs ppd methods
fit <- stan_glm(mpg ~ wt, data = mtcars, iter = 300)
preds <- posterior_predict(fit, seed = 123)
```

```

all.equal(
  predictive_error(fit, seed = 123),
  predictive_error(preds, y = fit$y)
)

```

predictive_interval.stanreg

Predictive intervals

Description

For models fit using MCMC (algorithm="sampling") or one of the variational approximations ("meanfield" or "fullrank"), the `predictive_interval` function computes Bayesian predictive intervals. The method for `stanreg` objects calls `posterior_predict` internally, whereas the method for objects of class "ppd" accepts the matrix returned by `posterior_predict` as input and can be used to avoid multiple calls to `posterior_predict`.

Usage

```

## S3 method for class 'stanreg'
predictive_interval(object, prob = 0.9,
  newdata = NULL, draws = NULL, re.form = NULL, fun = NULL,
  seed = NULL, offset = NULL, ...)

```

```

## S3 method for class 'ppd'
predictive_interval(object, prob = 0.9, ...)

```

Arguments

<code>object</code>	Either a fitted model object returned by one of the rstanarm modeling functions (a <code>stanreg</code> object) or, for the "ppd" method, a matrix of draws from the posterior predictive distribution returned by <code>posterior_predict</code> .
<code>prob</code>	A number $p \in (0, 1)$ indicating the desired probability mass to include in the intervals. The default is to report 90% intervals (prob=0.9) rather than the traditionally used 95% (see Details).
<code>newdata</code> , <code>draws</code> , <code>fun</code> , <code>offset</code> , <code>re.form</code> , <code>seed</code>	Passed to <code>posterior_predict</code> .
<code>...</code>	Currently ignored.

Value

A matrix with two columns and as many rows as are in `newdata`. If `newdata` is not provided then the matrix will have as many rows as the data used to fit the model. For a given value of `prob`, p , the columns correspond to the lower and upper $100p\%$ central interval limits and have the names $100\alpha/2\%$ and $100(1 - \alpha/2)\%$, where $\alpha = 1 - p$. For example, if `prob=0.9` is specified (a 90% interval), then the column names will be "5%" and "95%", respectively.

See Also

[predictive_error](#), [posterior_predict](#), [posterior_interval](#)

Examples

```
fit <- stan_glm(mpg ~ wt, data = mtcars, iter = 300)
predictive_interval(fit)
predictive_interval(fit, newdata = data.frame(wt = range(mtcars$wt)),
                    prob = 0.5)

# stanreg vs ppd methods
preds <- posterior_predict(fit, seed = 123)
all.equal(
  predictive_interval(fit, seed = 123),
  predictive_interval(preds)
)
```

print.stanreg	<i>Print method for stanreg objects</i>
---------------	---

Description

The print method for stanreg objects displays a compact summary of the fitted model. See the **Details** section below for descriptions of the different components of the printed output. For additional summary statistics and diagnostics use the [summary](#) method.

Usage

```
## S3 method for class 'stanreg'
print(x, digits = 1, ...)

## S3 method for class 'stanmvreg'
print(x, digits = 3, ...)
```

Arguments

x	A fitted model object returned by one of the rstanarm modeling functions. See stanreg-objects .
digits	Number of digits to use for formatting numbers.
...	Ignored.

Details

Point estimates: Regardless of the estimation algorithm, point estimates are medians computed from simulations. For models fit using MCMC ("sampling") the posterior sample is used. For optimization ("optimizing"), the simulations are generated from the asymptotic Gaussian sampling distribution of the parameters. For the "meanfield" and "fullrank" variational approximations, draws from the variational approximation to the posterior are used. In all cases, the point estimates reported are the same as the values returned by `coef`.

Uncertainty estimates (MAD_SD): The standard deviations reported (labeled MAD_SD in the print output) are computed from the same set of draws described above and are proportional to the median absolute deviation (`mad`) from the median. Compared to the raw posterior standard deviation, the MAD_SD will be more robust for long-tailed distributions. These are the same as the values returned by `se`.

Additional output:

- The median and MAD_SD are also reported for `mean_PPD`, the sample average posterior predictive distribution of the outcome. This is useful as a quick diagnostic. A useful heuristic is to check if `mean_PPD` is plausible when compared to `mean(y)`. If it is plausible then this does *not* mean that the model is good in general (only that it can reproduce the sample mean), however if `mean_PPD` is implausible then it is a sign that something is wrong (severe model misspecification, problems with the data, computational issues, etc.).
- For GLMs with group-specific terms (see `stan_glm`) the printed output also shows point estimates of the standard deviations of the group effects (and correlations if there are both intercept and slopes that vary by group).
- For analysis of variance models (see `stan_aov`) models, an ANOVA-like table is also displayed.
- For joint longitudinal and time-to-event (see `stan_jm`) models the estimates are presented separately for each of the distinct submodels.

Value

Returns `x`, invisibly.

See Also

[summary.stanreg](#), [stanreg-methods](#)

priors

Prior distributions and options

Description

The functions described on this page are used to specify the prior-related arguments of the various modeling functions in the **rstanarm** package (to view the priors used for an existing model see [prior_summary](#)).

The default priors used in the various **rstanarm** modeling functions are intended to be *weakly informative* in that they provide moderate regularization and help stabilize computation. For many applications the defaults will perform well, but prudent use of more informative priors is encouraged. Uniform prior distributions are possible (e.g. by setting `stan_glm`'s `prior` argument to `NULL`) but, unless the data is very strong, they are not recommended and are *not* non-informative, giving the same probability mass to implausible values as plausible ones.

More information on priors is available in the vignette *Prior Distributions for rstanarm Models* as well as the vignettes for the various modeling functions. In particular, for details on the priors used for multilevel models see the vignette *Estimating Generalized (Non-)Linear Models with Group-Specific Terms with rstanarm*.

Usage

```
normal(location = 0, scale = NULL, autoscale = TRUE)

student_t(df = 1, location = 0, scale = NULL, autoscale = TRUE)

cauchy(location = 0, scale = NULL, autoscale = TRUE)

hs(df = 1, global_df = 1, global_scale = 0.01, slab_df = 4,
   slab_scale = 2.5)

hs_plus(df1 = 1, df2 = 1, global_df = 1, global_scale = 0.01,
        slab_df = 4, slab_scale = 2.5)

laplace(location = 0, scale = NULL, autoscale = TRUE)

lasso(df = 1, location = 0, scale = NULL, autoscale = TRUE)

product_normal(df = 2, location = 0, scale = 1)

exponential(rate = 1, autoscale = TRUE)

decov(regularization = 1, concentration = 1, shape = 1, scale = 1)

lkj(regularization = 1, scale = 10, df = 1, autoscale = TRUE)

dirichlet(concentration = 1)

R2(location = NULL, what = c("mode", "mean", "median", "log"))
```

Arguments

<code>location</code>	Prior location. In most cases, this is the prior mean, but for <code>cauchy</code> (which is equivalent to <code>student_t</code> with <code>df=1</code>), the mean does not exist and <code>location</code> is the prior median. The default value is 0, except for <code>R2</code> which has no default value for <code>location</code> . For <code>R2</code> , <code>location</code> pertains to the prior location of the R^2 under a Beta distribution, but the interpretation of the <code>location</code> parameter depends on the specified value of the <code>what</code> argument (see the <i>R2 family</i> section in Details).
-----------------------	---

scale	Prior scale. The default depends on the family (see Details).
autoscale	A logical scalar, defaulting to TRUE. If TRUE then the scales of the priors on the intercept and regression coefficients may be additionally modified internally by rstanarm in the following cases. First, for Gaussian models only, the prior scales for the intercept, coefficients, and the auxiliary parameter sigma (error standard deviation) are multiplied by $sd(y)$. Additionally — not only for Gaussian models — if the QR argument to the model fitting function (e.g. <code>stan_glm</code>) is FALSE then: for a predictor with only one value nothing is changed; for a predictor x with exactly two unique values, we take the user-specified (or default) scale(s) for the selected priors and divide by the range of x ; for a predictor x with more than two unique values, we divide the prior scale(s) by $sd(x)$.
df, df1, df2	Prior degrees of freedom. The default is 1 for <code>student_t</code> , in which case it is equivalent to cauchy. For the hierarchical shrinkage priors (<code>hs</code> and <code>hs_plus</code>) the degrees of freedom parameter(s) default to 3. For the <code>product_normal</code> prior, the degrees of freedom parameter must be an integer (vector) that is at least 2 (the default).
global_df, global_scale, slab_df, slab_scale	Optional arguments for the hierarchical shrinkage priors. See the <i>Hierarchical shrinkage family</i> section below.
rate	Prior rate for the exponential distribution. Defaults to 1. For the exponential distribution, the rate parameter is the <i>reciprocal</i> of the mean.
regularization	Exponent for an LKJ prior on the correlation matrix in the <code>decov</code> or <code>lkj</code> prior. The default is 1, implying a joint uniform prior.
concentration	Concentration parameter for a symmetric Dirichlet distribution. The default is 1, implying a joint uniform prior.
shape	Shape parameter for a gamma prior on the scale parameter in the <code>decov</code> prior. If shape and scale are both 1 (the default) then the gamma prior simplifies to the unit-exponential distribution.
what	A character string among 'mode' (the default), 'mean', 'median', or 'log' indicating how the location parameter is interpreted in the LKJ case. If 'log', then location is interpreted as the expected logarithm of the R^2 under a Beta distribution. Otherwise, location is interpreted as the what of the R^2 under a Beta distribution. If the number of predictors is less than or equal to two, the mode of this Beta distribution does not exist and an error will prompt the user to specify another choice for what.

Details

The details depend on the family of the prior being used:

Student t family: Family members:

- `normal(location, scale)`
- `student_t(df, location, scale)`
- `cauchy(location, scale)`

Each of these functions also takes an argument `autoscale`.

For the prior distribution for the intercept, location, scale, and df should be scalars. For the prior for the other coefficients they can either be vectors of length equal to the number of coefficients (not including the intercept), or they can be scalars, in which case they will be recycled to the appropriate length. As the degrees of freedom approaches infinity, the Student t distribution approaches the normal distribution and if the degrees of freedom are one, then the Student t distribution is the Cauchy distribution.

If scale is not specified it will default to 10 for the intercept and 2.5 for the other coefficients, unless the probit link function is used, in which case these defaults are scaled by a factor of $d\text{norm}(\theta)/d\log\text{is}(\theta)$, which is roughly 1.6.

If the autoscale argument is TRUE (the default), then the scales will be further adjusted as described above in the documentation of the autoscale argument in the **Arguments** section.

Hierarchical shrinkage family: Family members:

- `hs(df, global_df, global_scale, slab_df, slab_scale)`
- `hs_plus(df1, df2, global_df, global_scale, slab_df, slab_scale)`

The hierarchical shrinkage priors are normal with a mean of zero and a standard deviation that is also a random variable. The traditional hierarchical shrinkage prior utilizes a standard deviation that is distributed half Cauchy with a median of zero and a scale parameter that is also half Cauchy. This is called the "horseshoe prior". The hierarchical shrinkage (hs) prior in the **rstanarm** package instead utilizes a regularized horseshoe prior, as described by Piironen and Vehtari (2017), which recommends setting the `global_scale` argument equal to the ratio of the expected number of non-zero coefficients to the expected number of zero coefficients, divided by the square root of the number of observations.

The hierarchical shrinkage plus (`hs_plus`) prior is similar except that the standard deviation that is distributed as the product of two independent half Cauchy parameters that are each scaled in a similar way to the hs prior.

The hierarchical shrinkage priors have very tall modes and very fat tails. Consequently, they tend to produce posterior distributions that are very concentrated near zero, unless the predictor has a strong influence on the outcome, in which case the prior has little influence. Hierarchical shrinkage priors often require you to increase the `adapt_delta` tuning parameter in order to diminish the number of divergent transitions. For more details on tuning parameters and divergent transitions see the Troubleshooting section of the *How to Use the rstanarm Package* vignette.

Laplace family: Family members:

- `laplace(location, scale)`
- `lasso(df, location, scale)`

Each of these functions also takes an argument `autoscale`.

The Laplace distribution is also known as the double-exponential distribution. It is a symmetric distribution with a sharp peak at its mean / median / mode and fairly long tails. This distribution can be motivated as a scale mixture of normal distributions and the remarks above about the normal distribution apply here as well.

The lasso approach to supervised learning can be expressed as finding the posterior mode when the likelihood is Gaussian and the priors on the coefficients have independent Laplace distributions. It is commonplace in supervised learning to choose the tuning parameter by cross-validation, whereas a more Bayesian approach would be to place a prior on "it", or rather its reciprocal in our case (i.e. *smaller* values correspond to more shrinkage toward the prior location vector). We

use a chi-square prior with degrees of freedom equal to that specified in the call to `lasso` or, by default, 1. The expectation of a chi-square random variable is equal to this degrees of freedom and the mode is equal to the degrees of freedom minus 2, if this difference is positive.

It is also common in supervised learning to standardize the predictors before training the model. We do not recommend doing so. Instead, it is better to specify `autoscale = TRUE` (the default value), which will adjust the scales of the priors according to the dispersion in the variables. See the documentation of the `autoscale` argument above and also the [prior_summary](#) page for more information.

Product-normal family: Family members:

- `product_normal(df, location, scale)`

The product-normal distribution is the product of at least two independent normal variates each with mean zero, shifted by the `location` parameter. It can be shown that the density of a product-normal variate is symmetric and infinite at `location`, so this prior resembles a “spike-and-slab” prior for sufficiently large values of the `scale` parameter. For better or for worse, this prior may be appropriate when it is strongly believed (by someone) that a regression coefficient “is” equal to the `location`, parameter even though no true Bayesian would specify such a prior.

Each element of `df` must be an integer of at least 2 because these “degrees of freedom” are interpreted as the number of normal variates being multiplied and then shifted by `location` to yield the regression coefficient. Higher degrees of freedom produce a sharper spike at `location`.

Each element of `scale` must be a non-negative real number that is interpreted as the standard deviation of the normal variates being multiplied and then shifted by `location` to yield the regression coefficient. In other words, the elements of `scale` may differ, but the `k`-th standard deviation is presumed to hold for all the normal deviates that are multiplied together and shifted by the `k`-th element of `location` to yield the `k`-th regression coefficient. The elements of `scale` are not the prior standard deviations of the regression coefficients. The prior variance of the regression coefficients is equal to the `scale` raised to the power of 2 times the corresponding element of `df`. Thus, larger values of `scale` put more prior volume on values of the regression coefficient that are far from zero.

Dirichlet family: Family members:

- `dirichlet(concentration)`

The Dirichlet distribution is a multivariate generalization of the beta distribution. It is perhaps the easiest prior distribution to specify because the `concentration` parameters can be interpreted as prior counts (although they need not be integers) of a multinomial random variable.

The Dirichlet distribution is used in `stan_polr` for an implicit prior on the cutpoints in an ordinal regression model. More specifically, the Dirichlet prior pertains to the prior probability of observing each category of the ordinal outcome when the predictors are at their sample means. Given these prior probabilities, it is straightforward to add them to form cumulative probabilities and then use an inverse CDF transformation of the cumulative probabilities to define the cutpoints.

If a scalar is passed to the `concentration` argument of the `dirichlet` function, then it is replicated to the appropriate length and the Dirichlet distribution is symmetric. If `concentration` is a vector and all elements are 1, then the Dirichlet distribution is jointly uniform. If all `concentration` parameters are equal but greater than 1 then the prior mode is that the categories are equiprobable, and the larger the value of the identical `concentration` parameters, the more sharply peaked the distribution is at the mode. The elements in `concentration` can also be given different values to represent that not all outcome categories are a priori equiprobable.

Covariance matrices: Family members:

- `decov(regularization, concentration, shape, scale)`
- `lkj(regularization, scale, df)`

(Also see vignette for `stan_glm`, *Estimating Generalized (Non-)Linear Models with Group-Specific Terms with `rstanarm`*)

Covariance matrices are decomposed into correlation matrices and variances. The variances are in turn decomposed into the product of a simplex vector and the trace of the matrix. Finally, the trace is the product of the order of the matrix and the square of a scale parameter. This prior on a covariance matrix is represented by the `decov` function.

The prior for a correlation matrix is called LKJ whose density is proportional to the determinant of the correlation matrix raised to the power of a positive regularization parameter minus one. If `regularization = 1` (the default), then this prior is jointly uniform over all correlation matrices of that size. If `regularization > 1`, then the identity matrix is the mode and in the unlikely case that `regularization < 1`, the identity matrix is the trough.

The trace of a covariance matrix is equal to the sum of the variances. We set the trace equal to the product of the order of the covariance matrix and the *square* of a positive scale parameter. The particular variances are set equal to the product of a simplex vector — which is non-negative and sums to 1 — and the scalar trace. In other words, each element of the simplex vector represents the proportion of the trace attributable to the corresponding variable.

A symmetric Dirichlet prior is used for the simplex vector, which has a single (positive) concentration parameter, which defaults to 1 and implies that the prior is jointly uniform over the space of simplex vectors of that size. If `concentration > 1`, then the prior mode corresponds to all variables having the same (proportion of total) variance, which can be used to ensure the the posterior variances are not zero. As the concentration parameter approaches infinity, this mode becomes more pronounced. In the unlikely case that `concentration < 1`, the variances are more polarized.

If all the variables were multiplied by a number, the trace of their covariance matrix would increase by that number squared. Thus, it is reasonable to use a scale-invariant prior distribution for the positive scale parameter, and in this case we utilize a Gamma distribution, whose shape and scale are both 1 by default, implying a unit-exponential distribution. Set the shape hyperparameter to some value greater than 1 to ensure that the posterior trace is not zero.

If `regularization`, `concentration`, `shape` and / or `scale` are positive scalars, then they are recycled to the appropriate length. Otherwise, each can be a positive vector of the appropriate length, but the appropriate length depends on the number of covariance matrices in the model and their sizes. A one-by-one covariance matrix is just a variance and thus does not have `regularization` or `concentration` parameters, but does have `shape` and `scale` parameters for the prior standard deviation of that variable.

Note that for `stan_mvmer` and `stan_jm` models an additional prior distribution is provided through the `lkj` function. This prior is in fact currently used as the default for those modelling functions (although `decov` is still available as an option if the user wishes to specify it through the `prior_covariance` argument). The `lkj` prior uses the same decomposition of the covariance matrices into correlation matrices and variances, however, the variances are not further decomposed into a simplex vector and the trace; instead the standard deviations (square root of the variances) for each of the group specific parameters are given a half Student t distribution with the `scale` and `df` parameters specified through the `scale` and `df` arguments to the `lkj` function. The `scale` parameter default is 10 which is then autoscaled, whilst the `df` parameter default is 1 (therefore equivalent to a half Cauchy prior distribution for the standard deviation of each group

specific parameter). This prior generally leads to similar results as the decov prior, but it is also likely to be *less* diffuse compared with the decov prior; therefore it sometimes seems to lead to faster estimation times, hence why it has been chosen as the default prior for `stan_mvmer` and `stan_jm` where estimation times can be long.

R2 family: Family members:

- `R2(location, what)`

The `stan_lm`, `stan_aov`, and `stan_polr` functions allow the user to utilize a function called `R2` to convey prior information about all the parameters. This prior hinges on prior beliefs about the location of R^2 , the proportion of variance in the outcome attributable to the predictors, which has a `Beta` prior with first shape hyperparameter equal to half the number of predictors and second shape hyperparameter free. By specifying `what` to be the prior mode (the default), mean, median, or expected log of R^2 , the second shape parameter for this Beta distribution is determined internally. If `what = 'log'`, location should be a negative scalar; otherwise it should be a scalar on the $(0, 1)$ interval.

For example, if $R^2 = 0.5$, then the mode, mean, and median of the `Beta` distribution are all the same and thus the second shape parameter is also equal to half the number of predictors. The second shape parameter of the `Beta` distribution is actually the same as the shape parameter in the LKJ prior for a correlation matrix described in the previous subsection. Thus, the smaller is R^2 , the larger is the shape parameter, the smaller are the prior correlations among the outcome and predictor variables, and the more concentrated near zero is the prior density for the regression coefficients. Hence, the prior on the coefficients is regularizing and should yield a posterior distribution with good out-of-sample predictions *if* the prior location of R^2 is specified in a reasonable fashion.

Value

A named list to be used internally by the `rstanarm` model fitting functions.

References

- Gelman, A., Carlin, J. B., Stern, H. S., Dunson, D. B., Vehtari, A., and Rubin, D. B. (2013). *Bayesian Data Analysis*. Chapman & Hall/CRC Press, London, third edition. <http://stat.columbia.edu/~gelman/book/>
- Gelman, A., Jakulin, A., Pittau, M. G., and Su, Y. (2008). A weakly informative default prior distribution for logistic and other regression models. *Annals of Applied Statistics*. 2(4), 1360–1383.
- Piironen, J., and Vehtari, A. (2017). Sparsity information and regularization in the horseshoe and other shrinkage priors. <https://arxiv.org/abs/1707.01694>
- Stan Development Team. (2017). *Stan Modeling Language Users Guide and Reference Manual*. <http://mc-stan.org/documentation/>

See Also

The various vignettes for the `rstanarm` package also discuss and demonstrate the use of some of the supported prior distributions.

Examples

```
fmla <- mpg ~ wt + qsec + drat + am

# Draw from prior predictive distribution (by setting prior_PD = TRUE)
prior_pred_fit <- stan_glm(fmla, data = mtcars, prior_PD = TRUE,
  chains = 1, seed = 12345, iter = 250, # for speed only
  prior = student_t(df = 4, 0, 2.5),
  prior_intercept = cauchy(0,10),
  prior_aux = exponential(1/2))
plot(prior_pred_fit, "hist")

# Can assign priors to names
N05 <- normal(0, 5)
fit <- stan_glm(fmla, data = mtcars, prior = N05, prior_intercept = N05)

# Visually compare normal, student_t, cauchy, laplace, and product_normal
compare_priors <- function(scale = 1, df_t = 2, xlim = c(-10, 10)) {
  dt_loc_scale <- function(x, df, location, scale) {
    1/scale * dt((x - location)/scale, df)
  }
  dlaplace <- function(x, location, scale) {
    0.5 / scale * exp(-abs(x - location) / scale)
  }
  dproduct_normal <- function(x, scale) {
    besselK(abs(x) / scale ^ 2, nu = 0) / (scale ^ 2 * pi)
  }
  stat_dist <- function(dist, ...) {
    ggplot2::stat_function(ggplot2::aes_(color = dist), ...)
  }
  ggplot2::ggplot(data.frame(x = xlim), ggplot2::aes(x)) +
    stat_dist("normal", size = .75, fun = dnorm,
      args = list(mean = 0, sd = scale)) +
    stat_dist("student_t", size = .75, fun = dt_loc_scale,
      args = list(df = df_t, location = 0, scale = scale)) +
    stat_dist("cauchy", size = .75, linetype = 2, fun = dcauchy,
      args = list(location = 0, scale = scale)) +
    stat_dist("laplace", size = .75, linetype = 2, fun = dlaplace,
      args = list(location = 0, scale = scale)) +
    stat_dist("product_normal", size = .75, linetype = 2, fun = dproduct_normal,
      args = list(scale = 1))
}
# Cauchy has fattest tails, followed by student_t, laplace, and normal
compare_priors()

# The student_t with df = 1 is the same as the cauchy
compare_priors(df_t = 1)

# Even a scale of 5 is somewhat large. It gives plausibility to rather
# extreme values
compare_priors(scale = 5, xlim = c(-20,20))
```

```
# If you use a prior like normal(0, 1000) to be "non-informative" you are
# actually saying that a coefficient value of e.g. -500 is quite plausible
compare_priors(scale = 1000, xlim = c(-1000,1000))
```

prior_summary.stanreg *Summarize the priors used for an rstanarm model*

Description

The `prior_summary` method provides a summary of the prior distributions used for the parameters in a given model. In some cases the user-specified prior does not correspond exactly to the prior used internally by **rstanarm** (see the sections below). Especially in these cases, but also in general, it can be much more useful to visualize the priors. Visualizing the priors can be done using the [posterior_vs_prior](#) function, or alternatively by fitting the model with the `prior_PD` argument set to `TRUE` (to draw from the prior predictive distribution instead of conditioning on the outcome) and then plotting the parameters.

Usage

```
## S3 method for class 'stanreg'
prior_summary(object, digits = 2, ...)
```

Arguments

<code>object</code>	A fitted model object returned by one of the rstanarm modeling functions. See stanreg-objects .
<code>digits</code>	Number of digits to use for rounding.
<code>...</code>	Currently ignored by the method for stanreg objects.

Value

A list of class "prior_summary.stanreg", which has its own print method.

Intercept (after predictors centered)

For **rstanarm** modeling functions that accept a `prior_intercept` argument, the specified prior for the intercept term applies to the intercept after **rstanarm** internally centers the predictors so they each have mean zero. The estimate of the intercept returned to the user correspond to the intercept with the predictors as specified by the user (unmodified by **rstanarm**), but when *specifying* the prior the intercept can be thought of as the expected outcome when the predictors are set to their means. The only exception to this is for models fit with the `sparse` argument set to `TRUE` (which is only possible with a subset of the modeling functions and never the default).

Adjusted scales

For some models you may see "adjusted scale" in the printed output and adjusted scales included in the object returned by `prior_summary`. These adjusted scale values are the prior scales actually used by **rstanarm** and are computed by adjusting the prior scales specified by the user to account for the scales of the predictors (as described in the documentation for the `autoscale` argument). To disable internal prior scale adjustments set the `autoscale` argument to `FALSE` when setting a prior using one of the distributions that accepts an `autoscale` argument. For example, `normal(0, 5, autoscale=FALSE)` instead of just `normal(0, 5)`.

Coefficients in Q-space

For the models fit with an **rstanarm** modeling function that supports the `QR` argument (see e.g., `stan_glm`), if `QR` is set to `TRUE` then the prior distributions for the regression coefficients specified using the `prior` argument are not relative to the original predictor variables X but rather to the variables in the matrix Q obtained from the QR decomposition of X .

In particular, if `prior = normal(location, scale)`, then this prior on the coefficients in Q -space can be easily translated into a joint multivariate normal (MVN) prior on the coefficients on the original predictors in X . Letting θ denote the coefficients on Q and β the coefficients on X then if $\theta \sim N(\mu, \sigma)$ the corresponding prior on β is $\beta \sim MVN(R\mu, R'R\sigma^2)$, where μ and σ are vectors of the appropriate length. Technically, **rstanarm** uses a scaled QR decomposition to ensure that the columns of the predictor matrix used to fit the model all have unit scale, when the `autoscale` argument to the function passed to the `prior` argument is `TRUE` (the default), in which case the matrices actually used are $Q^* = Q\sqrt{n-1}$ and $R^* = \frac{1}{\sqrt{n-1}}R$. If `autoscale = FALSE` we instead scale such that the lower-right element of R^* is 1, which is useful if you want to specify a prior on the coefficient of the last predictor in its original units (see the documentation for the `QR` argument).

If you are interested in the prior on β implied by the prior on θ , we strongly recommend visualizing it as described above in the **Description** section, which is simpler than working it out analytically.

See Also

The [priors help page](#) and the *Prior Distributions* vignette.

Examples

```
if (!exists("example_model")) example(example_model)
prior_summary(example_model)

priors <- prior_summary(example_model)
names(priors)
priors$prior$scale
priors$prior$adjusted_scale

# for a glm with adjusted scales (see Details, above), compare
# the default (rstanarm adjusting the scales) to setting
# autoscale=FALSE for prior on coefficients
fit <- stan_glm(mpg ~ wt + am, data = mtcars,
               prior = normal(0, c(2.5, 4)),
               prior_intercept = normal(0, 5),
               iter = 10, chains = 1) # only for demonstration
```

```
prior_summary(fit)

fit2 <- update(fit, prior = normal(0, c(2.5, 4), autoscale=FALSE),
              prior_intercept = normal(0, 5, autoscale=FALSE))
prior_summary(fit2)
```

ps_check

Graphical checks of the estimated survival function

Description

This function plots the estimated marginal survival function based on draws from the posterior predictive distribution of the fitted joint model, and then overlays the Kaplan-Meier curve based on the observed data.

Usage

```
ps_check(object, check = "survival", limits = c("ci", "none"),
         draws = NULL, seed = NULL, xlab = NULL, ylab = NULL,
         ci_geom_args = NULL, ...)
```

Arguments

object	A fitted model object returned by the stan_jm modelling function. See stanreg-objects .
check	The type of plot to show. Currently only "survival" is allowed, which compares the estimated marginal survival function under the joint model to the estimated Kaplan-Meier curve based on the observed data.
limits	A quoted character string specifying the type of limits to include in the plot. Can be one of: "ci" for the Bayesian posterior uncertainty interval (often known as a credible interval); or "none" for no interval limits.
draws	An integer indicating the number of MCMC draws to use to estimate the survival function. The default and maximum number of draws is the size of the posterior sample.
seed	An optional seed to use.
xlab, ylab	An optional axis label passed to labs .
ci_geom_args	Optional arguments passed to geom_ribbon and used to control features of the plotted interval limits. They should be supplied as a named list.
...	Optional arguments passed to geom_line and used to control features of the plotted trajectory.

Value

A ggplot object that can be further customized using the [ggplot2](#) package.

See Also

[posterior_survfit](#) for the estimated marginal or subject-specific survival function based on draws of the model parameters from the posterior distribution, [posterior_predict](#) for drawing from the posterior predictive distribution for the longitudinal submodel, and [pp_check](#) for graphical checks of the longitudinal submodel.

Examples

```
if (!exists("example_jm")) example(example_jm)
# Compare estimated survival function to Kaplan-Meier curve
ps <- ps_check(example_jm)
ps +
  ggplot2::scale_color_manual(values = c("red", "black")) + # change colors
  ggplot2::scale_size_manual(values = c(0.5, 3)) + # change line sizes
  ggplot2::scale_fill_manual(values = c(NA, NA)) # remove fill
```

QR-argument

The QR argument

Description

Details about the QR argument to **rstanarm**'s modeling functions.

Details

The QR argument is a logical scalar defaulting to FALSE, but if TRUE applies a scaled **qr** decomposition to the design matrix, $X = Q^*R^*$. If `autoscale = TRUE` (the default) in the call to the function passed to the prior argument, then $Q^* = Q\sqrt{n-1}$ and $R^* = \frac{1}{\sqrt{n-1}}R$. When `autoscale = FALSE`, R is scaled such that the lower-right element of R^* is 1.

The coefficients relative to Q^* are obtained and then premultiplied by the inverse of R^* to obtain coefficients relative to the original predictors, X . Thus, when `autoscale = FALSE`, the coefficient on the last column of X is the same as the coefficient on the last column of Q^* .

These transformations do not change the likelihood of the data but are recommended for computational reasons when there are multiple predictors. Importantly, while the columns of X are almost generally correlated, the columns of Q^* are uncorrelated by design, which often makes sampling from the posterior easier. However, because when QR is TRUE the prior argument applies to the coefficients relative to Q^* (and those are not very interpretable), setting QR=TRUE is only recommended if you do not have an informative prior for the regression coefficients or if the only informative prior is on the last regression coefficient (in which case you should set `autoscale = FALSE` when specifying such priors).

For more details see the Stan case study *The QR Decomposition For Regression Models* at http://mc-stan.org/users/documentation/case-studies/qr_regression.html.

References

Stan Development Team. (2017). *Stan Modeling Language Users Guide and Reference Manual*.
<http://mc-stan.org/documentation/>

rstanarm-datasets *Datasets for rstanarm examples*

Description

Small datasets for use in **rstanarm** examples and vignettes.

Format

bbal11970 Data on hits and at-bats from the 1970 Major League Baseball season for 18 players.

Source: Efron and Morris (1975).

18 obs. of 5 variables

- Player Player's last name
- Hits Number of hits in the first 45 at-bats of the season
- AB Number of at-bats (45 for all players)
- RemainingAB Number of remaining at-bats (different for most players)
- RemainingHits Number of remaining hits

bbal12006 Hits and at-bats for the entire 2006 American League season of Major League Baseball.

Source: Carpenter (2009)

302 obs. of 2 variables

- y Number of hits
- K Number of at-bats

kidiq Data from a survey of adult American women and their children (a subsample from the National Longitudinal Survey of Youth).

Source: Gelman and Hill (2007)

434 obs. of 4 variables

- kid_score Child's IQ score
- mom_hs Indicator for whether the mother has a high school degree
- mom_iq Mother's IQ score
- mom_age Mother's age

mortality Surgical mortality rates in 12 hospitals performing cardiac surgery in babies.

Source: Spiegelhalter et al. (1996).

12 obs. of 2 variables

- y Number of deaths
- K Number of surgeries

`pbclong`, `pbcsurv` Longitudinal biomarker and time-to-event survival data for 40 patients with primary biliary cirrhosis who participated in a randomised placebo controlled trial of D-penicillamine conducted at the Mayo Clinic between 1974 and 1984.

Source: Therneau and Grambsch (2000)

304 obs. of 8 variables (`pbclong`) and 40 obs. of 7 variables (`pbcsurv`)

- `age` age in years
- `albumin` serum albumin (g/dl)
- `logbili` logarithm of serum bilirubin
- `death` indicator of death at endpoint
- `ftimeyears` time (in years) between baseline and the earliest of death, transplantation or censoring
- `id` numeric ID unique to each individual
- `platelet` platelet count
- `sex` gender (m = male, f = female)
- `status` status at endpoint (0 = censored, 1 = transplant, 2 = dead)
- `trt` binary treatment code (0 = placebo, 1 = D-penicillamine)
- `year` time (in years) of the longitudinal measurements, taken as time since baseline)

`radon` Data on radon levels in houses in the state of Minnesota.

Source: Gelman and Hill (2007)

919 obs. of 4 variables

- `log_radon` Radon measurement from the house (log scale)
- `log_uranium` Uranium level in the county (log scale)
- `floor` Indicator for radon measurement made on the first floor of the house (0 = basement, 1 = first floor)
- `county` County name ([factor](#))

`roaches` Data on the efficacy of a pest management system at reducing the number of roaches in urban apartments.

Source: Gelman and Hill (2007)

262 obs. of 6 variables

- `y` Number of roaches caught
- `roach1` Pretreatment number of roaches
- `treatment` Treatment indicator
- `senior` Indicator for only elderly residents in building
- `exposure2` Number of days for which the roach traps were used

`tumors` Tarone (1982) provides a data set of tumor incidence in historical control groups of rats; specifically endometrial stromal polyps in female lab rats of type F344.

Source: Gelman and Hill (2007)

71 obs. of 2 variables

- `y` Number of rats with tumors
- `K` Number of rats

wells A survey of 3200 residents in a small area of Bangladesh suffering from arsenic contamination of groundwater. Respondents with elevated arsenic levels in their wells had been encouraged to switch their water source to a safe public or private well in the nearby area and the survey was conducted several years later to learn which of the affected residents had switched wells.

Source: Gelman and Hill (2007)

3020 obs. of 5 variables

- switch Indicator for well-switching
- arsenic Arsenic level in respondent's well
- dist Distance (meters) from the respondent's house to the nearest well with safe drinking water.
- association Indicator for member(s) of household participate in community organizations
- educ Years of education (head of household)

References

Carpenter, B. (2009) Bayesian estimators for the beta-binomial model of batting ability. <http://lingpipe-blog.com/2009/09/23/>

Efron, B. and Morris, C. (1975) Data analysis using Stein's estimator and its generalizations. *Journal of the American Statistical Association* **70**(350), 311–319.

Gelman, A. and Hill, J. (2007). *Data Analysis Using Regression and Multilevel/Hierarchical Models*. Cambridge University Press, Cambridge, UK. <http://stat.columbia.edu/~gelman/arm/>

Spiegelhalter, D., Thomas, A., Best, N., & Gilks, W. (1996) BUGS 0.5 Examples. MRC Biostatistics Unit, Institute of Public health, Cambridge, UK.

Tarone, R. E. (1982) The use of historical control information in testing for a trend in proportions. *Biometrics* **38**(1):215–220.

Therneau, T. and Grambsch, P. (2000) *Modeling Survival Data: Extending the Cox Model*. Springer-Verlag, New York, US.

Examples

```
# Using 'kidiq' dataset
fit <- stan_lm(kid_score ~ mom_hs * mom_iq, data = kidiq,
              prior = R2(location = 0.30, what = "mean"),
              # the next line is only to make the example go fast enough
              chains = 1, iter = 500, seed = 12345)
pp_check(fit, nreps = 20)

bayesplot::color_scheme_set("brightblue")
pp_check(fit, plotfun = "stat_grouped", stat = "median",
          group = factor(kidiq$mom_hs, labels = c("No HS", "HS")))
```

 rstanarm-deprecated *Deprecated functions*

Description

These functions are deprecated and will be removed in a future release. The **Arguments** section below provides details on how the functionality obtained via each of the arguments has been replaced.

Usage

```
prior_options(prior_scale_for_dispersion = 5, min_prior_scale = 1e-12,
              scaled = TRUE)
```

Arguments

prior_scale_for_dispersion, min_prior_scale, scaled

Arguments to deprecated prior_options function. The functionality provided by the now deprecated prior_options function has been replaced as follows:

prior_scale_for_dispersion Instead of using the prior_scale_for_dispersion argument to prior_options, priors for these parameters can now be specified directly when calling `stan_glm` (or `stan_glmer`, etc.) using the new `prior_aux` argument.

scaled Instead of setting `prior_options(scaled=FALSE)`, internal rescaling is now toggled using the new `autoscale` arguments to `normal`, `student_t`, and `cauchy` (the other prior distributions do not support 'autoscale').

min_prior_scale No replacement. `min_prior_scale` (the minimum possible scale parameter value that be used for priors) is now fixed to `1e-12`.

 stanmvreg-methods *Methods for stanmvreg objects*

Description

S3 methods for `stanmvreg` objects. There are also several methods (listed in **See Also**, below) with their own individual help pages. The main difference between these methods and the `stanreg` methods is that the methods described here generally include an additional argument `m` which allows the user to specify which submodel they wish to return the result for. If the argument `m` is set to `NULL` then the result will generally be a named list with each element of the list containing the result for one of the submodels.

Usage

```

## S3 method for class 'stanmvreg'
coef(object, m = NULL, ...)

## S3 method for class 'stanmvreg'
fitted(object, m = NULL, ...)

## S3 method for class 'stanmvreg'
residuals(object, m = NULL, ...)

## S3 method for class 'stanmvreg'
se(object, m = NULL, ...)

## S3 method for class 'stanmvreg'
formula(x, fixed.only = FALSE, random.only = FALSE,
        m = NULL, ...)

## S3 method for class 'stanmvreg'
update(object, formula., ..., evaluate = TRUE)

## S3 method for class 'stanjm'
update(object, formulaLong., formulaEvent., ...,
        evaluate = TRUE)

## S3 method for class 'stanmvreg'
fixef(object, m = NULL, remove_stub = TRUE, ...)

## S3 method for class 'stanmvreg'
ngrps(object, ...)

## S3 method for class 'stanmvreg'
ranef(object, m = NULL, ...)

## S3 method for class 'stanmvreg'
sigma(object, m = NULL, ...)

```

Arguments

object, x	A fitted model object returned by one of the multivariate rstanarm modelling functions. See stanreg-objects .
m	Integer specifying the number or name of the submodel
...	Ignored, except by the update method. See update .
fixed.only	A logical specifying whether to only retain the fixed effect part of the longitudinal submodel formulas
random.only	A logical specifying whether to only retain the random effect part of the longitudinal submodel formulas

formula.	An updated formula for the model. For a multivariate model formula. should be a list of formulas, as described for the formula argument in stan_mvmer .
evaluate	See update .
formulaLong., formulaEvent.	An updated formula for the longitudinal or event submodel, when object was estimated using stan_jm . For a multivariate joint model formulaLong. should be a list of formulas, as described for the formulaLong argument in stan_jm .
remove_stub	Logical specifying whether to remove the string identifying the submodel (e.g. y1 , y2 , Long1 , Long2 , Event) from each of the parameter names.

Details

Most of these methods are similar to the methods defined for objects of class 'lm', 'glm', 'glmer', etc. However there are a few exceptions:

coef Medians are used for point estimates. See the *Point estimates* section in [print.stanmvreg](#) for more details. `coef` returns a list equal to the length of the number of submodels. The first elements of the list are the coefficients from each of the fitted longitudinal submodels and are the same layout as those returned by `coef` method of the **lme4** package, that is, the sum of the random and fixed effects coefficients for each explanatory variable for each level of each grouping factor. The final element of the returned list is a vector of fixed effect coefficients from the event submodel.

se The `se` function returns standard errors based on [mad](#). See the *Uncertainty estimates* section in [print.stanmvreg](#) for more details.

confint Not supplied, since the [posterior_interval](#) function should be used instead to compute Bayesian uncertainty intervals.

residuals Residuals are *always* of type "response" (not "deviance" residuals or any other type).

See Also

- The [print](#), [summary](#), and [prior_summary](#) methods for `stanmvreg` objects for information on the fitted model.
- The [plot](#) method to plot estimates and diagnostics.
- The [pp_check](#) method for graphical posterior predictive checking of the longitudinal or `glmer` submodels.
- The [ps_check](#) method for graphical posterior predictive checking of the event submodel.
- The [posterior_traj](#) for predictions for the longitudinal submodel (for models estimated using [stan_jm](#)), as well as it's associated [plot](#) method.
- The [posterior_survfit](#) for predictions for the event submodel, including so-called "dynamic" predictions (for models estimated using [stan_jm](#)), as well as it's associated [plot](#) method.
- The [posterior_predict](#) for predictions for the `glmer` submodel (for models estimated using [stan_mvmer](#)).
- The [posterior_interval](#) for uncertainty intervals for model parameters.

- The `loo`, and `log_lik` methods for leave-one-out model comparison, and computing the log-likelihood of (possibly new) data.
- The `as.matrix`, `as.data.frame`, and `as.array` methods to access posterior draws.

Other S3 methods for `stanmvreg` objects, which have separate documentation, including `print.stanmvreg`, and `summary.stanmvreg`.

Also `posterior_interval` for an alternative to `confint`, and `posterior_predict`, `posterior_traj` and `posterior_survfit` for predictions based on the fitted joint model.

stanreg-methods

Methods for stanreg objects

Description

The methods documented on this page are actually some of the least important methods defined for `stanreg` objects. The most important methods are documented separately, each with its own page. Links to those pages are provided in the **See Also** section, below.

Usage

```
## S3 method for class 'stanreg'
coef(object, ...)

## S3 method for class 'stanreg'
confint(object, parm, level = 0.95, ...)

## S3 method for class 'stanreg'
fitted(object, ...)

## S3 method for class 'stanreg'
nobs(object, ...)

## S3 method for class 'stanreg'
residuals(object, ...)

## S3 method for class 'stanreg'
se(object, ...)

## S3 method for class 'stanreg'
update(object, formula., ..., evaluate = TRUE)

## S3 method for class 'stanreg'
vcov(object, correlation = FALSE, ...)

## S3 method for class 'stanreg'
fixef(object, ...)
```

```
## S3 method for class 'stanreg'
ngrps(object, ...)

## S3 method for class 'stanreg'
ranef(object, ...)

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

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

Arguments

object, x	A fitted model object returned by one of the rstanarm modeling functions. See stanreg-objects .
...	Ignored, except by the update method. See update .
parm	For confint, an optional character vector of parameter names.
level	For confint, a scalar between 0 and 1 indicating the confidence level to use.
formula., evaluate	See update .
correlation	For vcov, if FALSE (the default) the covariance matrix is returned. If TRUE, the correlation matrix is returned instead.
sigma	Ignored (included for compatibility with VarCorr).

Details

The methods documented on this page are similar to the methods defined for objects of class 'lm', 'glm', 'glmer', etc. However there are a few key differences:

residuals Residuals are *always* of type "response" (not "deviance" residuals or any other type). However, in the case of [stan_polr](#) with more than two response categories, the residuals are the difference between the latent utility and its linear predictor.

coef Medians are used for point estimates. See the *Point estimates* section in [print.stanreg](#) for more details.

se The se function returns standard errors based on [mad](#). See the *Uncertainty estimates* section in [print.stanreg](#) for more details.

confint For models fit using optimization, confidence intervals are returned via a call to [confint.default](#). If algorithm is "sampling", "meanfield", or "fullrank", the confint will throw an error because the [posterior_interval](#) function should be used to compute Bayesian uncertainty intervals.

See Also

- The [print](#), [summary](#), and [prior_summary](#) methods for stanreg objects for information on the fitted model.

- [launch_shinystan](#) to use the ShinyStan GUI to explore a fitted **rstanarm** model.
- The [plot](#) method to plot estimates and diagnostics.
- The [pp_check](#) method for graphical posterior predictive checking.
- The [posterior_predict](#) and [predictive_error](#) methods for predictions and predictive errors.
- The [posterior_interval](#) and [predictive_interval](#) methods for uncertainty intervals for model parameters and predictions.
- The [loo](#), [kfold](#), and [log_lik](#) methods for leave-one-out or K-fold cross-validation, model comparison, and computing the log-likelihood of (possibly new) data.
- The [as.matrix](#), [as.data.frame](#), and [as.array](#) methods to access posterior draws.

 stanreg-objects

Fitted model objects

Description

The **rstanarm** model-fitting functions return an object of class 'stanreg', which is a list containing at a minimum the components listed below. Each stanreg object will also have additional classes (e.g. 'aov', 'betareg', 'glm', 'polr', etc.) and several additional components depending on the model and estimation algorithm.

Some additional details apply to models estimated using the [stan_mvmer](#) or [stan_jm](#) modelling functions. The [stan_mvmer](#) modelling function returns an object of class 'stanmvreg', which inherits the 'stanreg' class, but has a number of additional elements described in the subsection below. The [stan_jm](#) modelling function returns an object of class 'stanjm', which inherits both the 'stanmvreg' and 'stanreg' classes, but has a number of additional elements described in the subsection below. Both the 'stanjm' and 'stanmvreg' classes have several of their own methods for situations in which the default 'stanreg' methods are not suitable; see the **See Also** section below.

Elements for stanreg objects

`coefficients` Point estimates, as described in [print.stanreg](#).

`ses` Standard errors based on `mad`, as described in [print.stanreg](#).

`residuals` Residuals of type 'response'.

`fitted.values` Fitted mean values. For GLMs the linear predictors are transformed by the inverse link function.

`linear.predictors` Linear fit on the link scale. For linear models this is the same as `fitted.values`.

`covmat` Variance-covariance matrix for the coefficients based on draws from the posterior distribution, the variational approximation, or the asymptotic sampling distribution, depending on the estimation algorithm.

`model,x,y` If requested, the the model frame, model matrix and response variable used, respectively.

`family` The `family` object used.
`call` The matched call.
`formula` The model `formula`.
`data, offset, weights` The data, offset, and weights arguments.
`algorithm` The estimation method used.
`prior.info` A list with information about the prior distributions used.
`stanfit, stan_summary` The object of `stanfit-class` returned by RStan and a matrix of various summary statistics from the stanfit object.
`rstan_version` The version of the `rstan` package that was used to fit the model.

Elements for stanmvreg objects

The stanmvreg objects contain the majority of the elements described above for stanreg objects, but in most cases these will be a list with each elements of the list corresponding to one of the submodels (for example, the `family` element of a stanmvreg object will be a list with each element of the list containing the `family` object for one submodel). In addition, stanmvreg objects contain the following additional elements:

The names of the grouping factors and group specific parameters, collapsed across the longitudinal or glmer submodels.

`levels` The unique factor levels for each grouping factor, collapsed across the longitudinal or glmer submodels.
`n_markers` The number of longitudinal or glmer submodels.
`n_yobs` The number of observations for each longitudinal or glmer submodel.
`n_grps` The number of levels for each grouping factor (for models estimated using `stan_jm`, this will be equal to `n_subjects` if the individual is the only grouping factor).
`runtime` The time taken to fit the model (in minutes).

Additional elements for stanjm objects

The stanjm objects contain the elements described above for stanmvreg objects, but also contain the following additional elements:

The names of the variables distinguishing between individuals, and representing time in the longitudinal submodel.

`id_var, time_var, n_subjects` The number of individuals.
`n_events` The number of non-censored events.
`eventtime, status` The event (or censoring) time and status indicator for each individual.
`basehaz` A list containing information about the baseline hazard.
`assoc` An array containing information about the association structure.
`epsilon` The width of the one-sided difference used to numerically evaluate the slope of the longitudinal trajectory; only relevant if a slope-based association structure was specified (e.g. `etaslope`, `muslope`, etc).
`qnodes` The number of Gauss-Kronrod quadrature nodes used to evaluate the cumulative hazard in the joint likelihood function.

Note

The `stan_biglm` function is an exception. It returns a `stanfit` object rather than a `stanreg` object.

See Also

[stanreg-methods](#), [stanmvreg-methods](#)

stanreg_list	<i>Create a list of fitted model objects</i>
--------------	--

Description

Create a list of fitted model objects

Usage

```
stanreg_list(...)
```

```
stanmvreg_list(...)
```

```
stanjm_list(...)
```

Arguments

... One or more fitted model objects.

Value

A list of class "stanreg_list", "stanmvreg_list", or "stanjm_list", containing the fitted model objects and some metadata stored as attributes.

See Also

[loo_model_weights](#) for usage of `stanreg_list`.

Description

Bayesian inference for linear modeling with regularizing priors on the model parameters that are driven by prior beliefs about R^2 , the proportion of variance in the outcome attributable to the predictors. See [priors](#) for an explanation of this critical point. `stan_glm` with `family="gaussian"` also estimates a linear model with normally-distributed errors and allows for various other priors on the coefficients.

Usage

```
stan_aov(formula, data, projections = FALSE, contrasts = NULL, ...,
  prior = R2(stop("'location' must be specified")), prior_PD = FALSE,
  algorithm = c("sampling", "meanfield", "fullrank"),
  adapt_delta = NULL)
```

```
stan_lm(formula, data, subset, weights, na.action, model = TRUE,
  x = FALSE, y = FALSE, singular.ok = TRUE, contrasts = NULL,
  offset, ..., prior = R2(stop("'location' must be specified")),
  prior_intercept = NULL, prior_PD = FALSE, algorithm = c("sampling",
  "meanfield", "fullrank"), adapt_delta = NULL)
```

```
stan_lm.wfit(x, y, w, offset = NULL, singular.ok = TRUE, ...,
  prior = R2(stop("'location' must be specified")),
  prior_intercept = NULL, prior_PD = FALSE, algorithm = c("sampling",
  "meanfield", "fullrank"), adapt_delta = NULL)
```

```
stan_lm.fit(x, y, offset = NULL, singular.ok = TRUE, ...,
  prior = R2(stop("'location' must be specified")),
  prior_intercept = NULL, prior_PD = FALSE, algorithm = c("sampling",
  "meanfield", "fullrank"), adapt_delta = NULL)
```

Arguments

- | | |
|-----------------------|---|
| formula, data, subset | Same as <code>lm</code> , but <i>we strongly advise against omitting the data argument</i> . Unless data is specified (and is a data frame) many post-estimation functions (including <code>update</code> , <code>loo</code> , <code>kfold</code>) are not guaranteed to work properly. |
| projections | For <code>stan_aov</code> , a logical scalar (defaulting to <code>FALSE</code>) indicating whether <code>proj</code> should be called on the fit. |
| ... | Further arguments passed to the function in the <code>rstan</code> package (<code>sampling</code> , <code>vb</code> , or <code>optimizing</code>), corresponding to the estimation method named by <code>algorithm</code> . For example, if <code>algorithm</code> is "sampling" it is possible to specify <code>iter</code> , <code>chains</code> , <code>cores</code> , <code>refresh</code> , etc. |

prior	Must be a call to <code>R2</code> with its location argument specified or <code>NULL</code> , which would indicate a standard uniform prior for the R^2 .
prior_PD	A logical scalar (defaulting to <code>FALSE</code>) indicating whether to draw from the prior predictive distribution instead of conditioning on the outcome.
algorithm	A string (possibly abbreviated) indicating the estimation approach to use. Can be "sampling" for MCMC (the default), "optimizing" for optimization, "meanfield" for variational inference with independent normal distributions, or "fullrank" for variational inference with a multivariate normal distribution. See rstanarm-package for more details on the estimation algorithms. NOTE: not all fitting functions support all four algorithms.
adapt_delta	Only relevant if <code>algorithm="sampling"</code> . See the adapt_delta help page for details.
na.action, singular.ok, contrasts	Same as <code>lm</code> , but rarely specified.
model, offset, weights	Same as <code>lm</code> , but rarely specified.
x, y	In <code>stan_lm</code> , <code>stan_aov</code> , logical scalars indicating whether to return the design matrix and response vector. In <code>stan_lm.fit</code> or <code>stan_lm.wfit</code> , a design matrix and response vector.
prior_intercept	<p>Either <code>NULL</code> (the default) or a call to <code>normal</code>. If a <code>normal</code> prior is specified without a scale, then the standard deviation is taken to be the marginal standard deviation of the outcome divided by the square root of the sample size, which is legitimate because the marginal standard deviation of the outcome is a primitive parameter being estimated.</p> <p>Note: If using a dense representation of the design matrix —i.e., if the <code>sparse</code> argument is left at its default value of <code>FALSE</code>— then the prior distribution for the intercept is set so it applies to the value <i>when all predictors are centered</i>. If you prefer to specify a prior on the intercept without the predictors being auto-centered, then you have to omit the intercept from the <code>formula</code> and include a column of ones as a predictor, in which case some element of <code>prior</code> specifies the prior on it, rather than <code>prior_intercept</code>. Regardless of how <code>prior_intercept</code> is specified, the reported <i>estimates</i> of the intercept always correspond to a parameterization without centered predictors (i.e., same as in <code>glm</code>).</p>
w	Same as in <code>lm.wfit</code> but rarely specified.

Details

The `stan_lm` function is similar in syntax to the `lm` function but rather than choosing the parameters to minimize the sum of squared residuals, samples from the posterior distribution are drawn using MCMC (if `algorithm` is "sampling"). The `stan_lm` function has a formula-based interface and would usually be called by users but the `stan_lm.fit` and `stan_lm.wfit` functions might be called by other functions that parse the data themselves and are analogous to `lm.fit` and `lm.wfit` respectively.

In addition to estimating σ — the standard deviation of the normally-distributed errors — this model estimates a positive parameter called `log-fit_ratio`. If it is positive, the marginal

posterior variance of the outcome will exceed the sample variance of the outcome by a multiplicative factor equal to the square of `fit_ratio`. Conversely if `log-fit_ratio` is negative, then the model underfits. Given the regularizing nature of the priors, a slight underfit is good.

Finally, the posterior predictive distribution is generated with the predictors fixed at their sample means. This quantity is useful for checking convergence because it is reasonably normally distributed and a function of all the parameters in the model.

The `stan_aov` function is similar to `aov`, but does a Bayesian analysis of variance that is basically equivalent to `stan_lm` with dummy variables. `stan_aov` has a somewhat customized `print` method that prints an ANOVA-like table in addition to the output printed for `stan_lm` models.

Value

A `stanreg` object is returned for `stan_lm`, `stan_aov`.

A `stanfit` object (or a slightly modified `stanfit` object) is returned if `stan_lm.fit` or `stan_lm.wfit` is called directly.

References

Lewandowski, D., Kurowicka D., and Joe, H. (2009). Generating random correlation matrices based on vines and extended onion method. *Journal of Multivariate Analysis*. **100**(9), 1989–2001.

See Also

The vignettes for `stan_lm` and `stan_aov`, which have more thorough descriptions and examples. <http://mc-stan.org/rstanarm/articles/>

Also see `stan_glm`, which — if `family = gaussian(link="identity")` — also estimates a linear model with normally-distributed errors but specifies different priors.

Examples

```
op <- options(contrasts = c("contr.helmert", "contr.poly"))
fit_aov <- stan_aov(yield ~ block + N*P*K, data = npk,
  prior = R2(0.5), seed = 12345)
options(op)
print(fit_aov)

(fit <- stan_lm(mpg ~ wt + qsec + am, data = mtcars, prior = R2(0.75),
  # the next line is only to make the example go fast enough
  chains = 1, iter = 500, seed = 12345))
plot(fit, prob = 0.8)
plot(fit, "hist", pars = c("wt", "am", "qsec", "sigma"),
  transformations = list(sigma = "log"))
```

 stan_betareg

Bayesian beta regression models via Stan

Description

Beta regression modeling with optional prior distributions for the coefficients, intercept, and auxiliary parameter phi (if applicable).

Usage

```
stan_betareg(formula, data, subset, na.action, weights, offset,
  link = c("logit", "probit", "cloglog", "cauchit", "log", "loglog"),
  link.phi = NULL, model = TRUE, y = TRUE, x = FALSE, ...,
  prior = normal(), prior_intercept = normal(), prior_z = normal(),
  prior_intercept_z = normal(), prior_phi = exponential(),
  prior_PD = FALSE, algorithm = c("sampling", "optimizing",
  "meanfield", "fullrank"), adapt_delta = NULL, QR = FALSE)
```

```
stan_betareg.fit(x, y, z = NULL, weights = rep(1, NROW(x)),
  offset = rep(0, NROW(x)), link = c("logit", "probit", "cloglog",
  "cauchit", "log", "loglog"), link.phi = NULL, ..., prior = normal(),
  prior_intercept = normal(), prior_z = normal(),
  prior_intercept_z = normal(), prior_phi = exponential(),
  prior_PD = FALSE, algorithm = c("sampling", "optimizing",
  "meanfield", "fullrank"), adapt_delta = NULL, QR = FALSE)
```

Arguments

formula, data, subset	Same as betareg , but <i>we strongly advise against omitting the data argument</i> . Unless data is specified (and is a data frame) many post-estimation functions (including update, loo, kfold) are not guaranteed to work properly.
na.action	Same as betareg , but rarely specified.
link	Character specification of the link function used in the model for mu (specified through x). Currently, "logit", "probit", "cloglog", "cauchit", "log", and "loglog" are supported.
link.phi	If applicable, character specification of the link function used in the model for phi (specified through z). Currently, "identity", "log" (default), and "sqrt" are supported. Since the "sqrt" link function is known to be unstable, it is advisable to specify a different link function (or to model phi as a scalar parameter instead of via a linear predictor by excluding z from the formula and excluding link.phi).
model, offset, weights	Same as betareg .

x, y	In stan_betareg, logical scalars indicating whether to return the design matrix and response vector. In stan_betareg.fit, a design matrix and response vector.
...	Further arguments passed to the function in the rstan package (sampling , vb , or optimizing), corresponding to the estimation method named by algorithm. For example, if algorithm is "sampling" it is possible to specify iter, chains, cores, refresh, etc.
prior	The prior distribution for the regression coefficients. prior should be a call to one of the various functions provided by rstanarm for specifying priors. The subset of these functions that can be used for the prior on the coefficients can be grouped into several "families":

Family	Functions
<i>Student t family</i>	normal, student_t, cauchy
<i>Hierarchical shrinkage family</i>	hs, hs_plus
<i>Laplace family</i>	laplace, lasso
<i>Product normal family</i>	product_normal

See the [priors help page](#) for details on the families and how to specify the arguments for all of the functions in the table above. To omit a prior—i.e., to use a flat (improper) uniform prior—prior can be set to NULL, although this is rarely a good idea.

Note: Unless QR=TRUE, if prior is from the Student t family or Laplace family, and if the autoscale argument to the function used to specify the prior (e.g. [normal](#)) is left at its default and recommended value of TRUE, then the default or user-specified prior scale(s) may be adjusted internally based on the scales of the predictors. See the [priors help page](#) and the *Prior Distributions* vignette for details on the rescaling and the [prior_summary](#) function for a summary of the priors used for a particular model.

prior_intercept	The prior distribution for the intercept. prior_intercept can be a call to normal, student_t or cauchy. See the priors help page for details on these functions. To omit a prior on the intercept—i.e., to use a flat (improper) uniform prior—prior_intercept can be set to NULL. Note: If using a dense representation of the design matrix—i.e., if the sparse argument is left at its default value of FALSE—then the prior distribution for the intercept is set so it applies to the value <i>when all predictors are centered</i> . If you prefer to specify a prior on the intercept without the predictors being auto-centered, then you have to omit the intercept from the formula and include a column of ones as a predictor, in which case some element of prior specifies the prior on it, rather than prior_intercept. Regardless of how prior_intercept is specified, the reported <i>estimates</i> of the intercept always correspond to a parameterization without centered predictors (i.e., same as in glm).
prior_z	Prior distribution for the coefficients in the model for phi (if applicable). Same options as for prior.

prior_intercept_z	Prior distribution for the intercept in the model for phi (if applicable). Same options as for prior_intercept.
prior_phi	The prior distribution for phi if it is <i>not</i> modeled as a function of predictors. If z variables are specified then prior_phi is ignored and prior_intercept_z and prior_z are used to specify the priors on the intercept and coefficients in the model for phi. When applicable, prior_phi can be a call to exponential to use an exponential distribution, or one of normal, student_t or cauchy to use half-normal, half-t, or half-Cauchy prior. See priors for details on these functions. To omit a prior —i.e., to use a flat (improper) uniform prior— set prior_phi to NULL.
prior_PD	A logical scalar (defaulting to FALSE) indicating whether to draw from the prior predictive distribution instead of conditioning on the outcome.
algorithm	A string (possibly abbreviated) indicating the estimation approach to use. Can be "sampling" for MCMC (the default), "optimizing" for optimization, "meanfield" for variational inference with independent normal distributions, or "fullrank" for variational inference with a multivariate normal distribution. See rstanarm-package for more details on the estimation algorithms. NOTE: not all fitting functions support all four algorithms.
adapt_delta	Only relevant if algorithm="sampling". See the adapt_delta help page for details.
QR	A logical scalar defaulting to FALSE, but if TRUE applies a scaled qr decomposition to the design matrix. The transformation does not change the likelihood of the data but is recommended for computational reasons when there are multiple predictors. See the QR-argument documentation page for details on how rstanarm does the transformation and important information about how to interpret the prior distributions of the model parameters when using QR=TRUE.
z	For stan_betareg.fit, a regressor matrix for phi. Defaults to an intercept only.

Details

The stan_betareg function is similar in syntax to [betareg](#) but rather than performing maximum likelihood estimation, full Bayesian estimation is performed (if algorithm is "sampling") via MCMC. The Bayesian model adds priors (independent by default) on the coefficients of the beta regression model. The stan_betareg function calls the workhorse stan_betareg.fit function, but it is also possible to call the latter directly.

Value

A [stanreg](#) object is returned for stan_betareg.

A [stanfit](#) object (or a slightly modified stanfit object) is returned if stan_betareg.fit is called directly.

References

Ferrari, SLP and Cribari-Neto, F (2004). Beta regression for modeling rates and proportions. *Journal of Applied Statistics*. 31(7), 799–815.

See Also

[stanreg-methods](#) and [betareg](#).

The vignette for stan_betareg. <http://mc-stan.org/rstanarm/articles/>

Examples

```
### Simulated data
N <- 200
x <- rnorm(N, 2, 1)
z <- rnorm(N, 2, 1)
mu <- binomial(link = "logit")$linkinv(1 + 0.2*x)
phi <- exp(1.5 + 0.4*z)
y <- rbeta(N, mu * phi, (1 - mu) * phi)
hist(y, col = "dark grey", border = FALSE, xlim = c(0,1))
fake_dat <- data.frame(y, x, z)

fit <- stan_betareg(
  y ~ x | z, data = fake_dat,
  link = "logit",
  link.phi = "log",
  algorithm = "optimizing" # just for speed of example
)
print(fit, digits = 2)
```

 stan_biglm

Bayesian regularized linear but big models via Stan

Description

This is the same model as with [stan_lm](#) but it utilizes the output from [biglm](#) in the **biglm** package in order to proceed when the data is too large to fit in memory.

Usage

```
stan_biglm(biglm, xbar, ybar, s_y, ...,
  prior = R2(stop("'location' must be specified")),
  prior_intercept = NULL, prior_PD = FALSE, algorithm = c("sampling",
  "meanfield", "fullrank"), adapt_delta = NULL)

stan_biglm.fit(b, R, SSR, N, xbar, ybar, s_y, has_intercept = TRUE, ...,
  prior = R2(stop("'location' must be specified")),
  prior_intercept = NULL, prior_PD = FALSE, algorithm = c("sampling",
  "meanfield", "fullrank"), adapt_delta = NULL)
```

Arguments

biglm	The list output by <code>biglm</code> in the biglm package.
xbar	A numeric vector of column means in the implicit design matrix excluding the intercept for the observations included in the model.
ybar	A numeric scalar indicating the mean of the outcome for the observations included in the model.
s_y	A numeric scalar indicating the unbiased sample standard deviation of the outcome for the observations included in the model.
...	Further arguments passed to the function in the rstan package (<code>sampling</code> , <code>vb</code> , or <code>optimizing</code>), corresponding to the estimation method named by <code>algorithm</code> . For example, if <code>algorithm</code> is "sampling" it is possible to specify <code>iter</code> , <code>chains</code> , <code>cores</code> , <code>refresh</code> , etc.
prior	Must be a call to <code>R2</code> with its <code>location</code> argument specified or <code>NULL</code> , which would indicate a standard uniform prior for the R^2 .
prior_intercept	<p>Either <code>NULL</code> (the default) or a call to <code>normal</code>. If a <code>normal</code> prior is specified without a scale, then the standard deviation is taken to be the marginal standard deviation of the outcome divided by the square root of the sample size, which is legitimate because the marginal standard deviation of the outcome is a primitive parameter being estimated.</p> <p>Note: If using a dense representation of the design matrix —i.e., if the <code>sparse</code> argument is left at its default value of <code>FALSE</code>— then the prior distribution for the intercept is set so it applies to the value <i>when all predictors are centered</i>. If you prefer to specify a prior on the intercept without the predictors being auto-centered, then you have to omit the intercept from the <code>formula</code> and include a column of ones as a predictor, in which case some element of <code>prior</code> specifies the prior on it, rather than <code>prior_intercept</code>. Regardless of how <code>prior_intercept</code> is specified, the reported <i>estimates</i> of the intercept always correspond to a parameterization without centered predictors (i.e., same as in <code>glm</code>).</p>
prior_PD	A logical scalar (defaulting to <code>FALSE</code>) indicating whether to draw from the prior predictive distribution instead of conditioning on the outcome.
algorithm	A string (possibly abbreviated) indicating the estimation approach to use. Can be "sampling" for MCMC (the default), "optimizing" for optimization, "meanfield" for variational inference with independent normal distributions, or "fullrank" for variational inference with a multivariate normal distribution. See rstanarm-package for more details on the estimation algorithms. NOTE: not all fitting functions support all four algorithms.
adapt_delta	Only relevant if <code>algorithm="sampling"</code> . See the adapt_delta help page for details.
b	A numeric vector of OLS coefficients, excluding the intercept
R	A square upper-triangular matrix from the QR decomposition of the design matrix, excluding the intercept
SSR	A numeric scalar indicating the sum-of-squared residuals for OLS
N	A integer scalar indicating the number of included observations

`has_intercept` A logical scalar indicating whether to add an intercept to the model when estimating it.

Details

The `stan_biglm` function is intended to be used in the same circumstances as the `biglm` function in the **biglm** package but with an informative prior on the R^2 of the regression. Like `biglm`, the memory required to estimate the model depends largely on the number of predictors rather than the number of observations. However, `stan_biglm` and `stan_biglm.fit` have additional required arguments that are not necessary in `biglm`, namely `xbar`, `ybar`, and `s_y`. If any observations have any missing values on any of the predictors or the outcome, such observations do not contribute to these statistics.

Value

The output of both `stan_biglm` and `stan_biglm.fit` is an object of `stanfit-class` rather than `stanreg-objects`, which is more limited and less convenient but necessitated by the fact that `stan_biglm` does not bring the full design matrix into memory. Without the full design matrix, some of the elements of a `stanreg-objects` object cannot be calculated, such as residuals. Thus, the functions in the **rstanarm** package that input `stanreg-objects`, such as `posterior_predict` cannot be used.

Examples

```
# create inputs
ols <- lm(mpg ~ wt + qsec + am, data = mtcars, # all row are complete so ...
          na.action = na.exclude)           # not necessary in this case
b <- coef(ols)[-1]
R <- qr.R(ols$qr)[-1,-1]
SSR <- crossprod(ols$residuals)[1]
not_NA <- !is.na(fitted(ols))
N <- sum(not_NA)
xbar <- colMeans(mtcars[not_NA,c("wt", "qsec", "am")])
y <- mtcars$mpg[not_NA]
ybar <- mean(y)
s_y <- sd(y)
post <- stan_biglm.fit(b, R, SSR, N, xbar, ybar, s_y, prior = R2(.75),
                      # the next line is only to make the example go fast
                      chains = 1, iter = 500, seed = 12345)
cbind(lm = b, stan_lm = rstan::get_posterior_mean(post)[13:15,]) # shrunk
```

stan_clogit

Conditional logistic (clogit) regression models via Stan

Description

A model for case-control studies with optional prior distributions for the coefficients, intercept, and auxiliary parameters.

Usage

```
stan_clogit(formula, data, subset, na.action = NULL, ..., strata,
            prior = normal(), prior_covariance = decov(), prior_PD = FALSE,
            algorithm = c("sampling", "optimizing", "meanfield", "fullrank"),
            adapt_delta = NULL, QR = FALSE, sparse = FALSE)
```

Arguments

`formula`, `data`, `subset`, `na.action`
 Same as for `glmer`, except that any global intercept included in the formula will be dropped. *We strongly advise against omitting the data argument.* Unless `data` is specified (and is a data frame) many post-estimation functions (including `update`, `loo`, `kfold`) are not guaranteed to work properly.

`...`
 Further arguments passed to the function in the `rstan` package (`sampling`, `vb`, or `optimizing`), corresponding to the estimation method named by `algorithm`. For example, if `algorithm` is "sampling" it is possible to specify `iter`, `chains`, `cores`, `refresh`, etc.

`strata`
 A factor indicating the groups in the data where the number of successes (possibly one) is fixed by the research design. It may be useful to use `interaction` or `strata` to create this factor. However, the `strata` argument must not rely on any object besides the data `data.frame`.

`prior`
 The prior distribution for the regression coefficients. `prior` should be a call to one of the various functions provided by `rstanarm` for specifying priors. The subset of these functions that can be used for the prior on the coefficients can be grouped into several "families":

Family	Functions
<i>Student t family</i>	normal, student_t, cauchy
<i>Hierarchical shrinkage family</i>	hs, hs_plus
<i>Laplace family</i>	laplace, lasso
<i>Product normal family</i>	product_normal

See the [priors help page](#) for details on the families and how to specify the arguments for all of the functions in the table above. To omit a prior—i.e., to use a flat (improper) uniform prior—`prior` can be set to `NULL`, although this is rarely a good idea.

Note: Unless `QR=TRUE`, if `prior` is from the Student t family or Laplace family, and if the `autoscale` argument to the function used to specify the prior (e.g. `normal`) is left at its default and recommended value of `TRUE`, then the default or user-specified prior scale(s) may be adjusted internally based on the scales of the predictors. See the [priors help page](#) and the *Prior Distributions* vignette for details on the rescaling and the `prior_summary` function for a summary of the priors used for a particular model.

`prior_covariance`
 Cannot be `NULL` when lme4-style group-specific terms are included in the formula. See `decov` for more information about the default arguments. Ignored when

	there are no group-specific terms.
prior_PD	A logical scalar (defaulting to FALSE) indicating whether to draw from the prior predictive distribution instead of conditioning on the outcome.
algorithm	A string (possibly abbreviated) indicating the estimation approach to use. Can be "sampling" for MCMC (the default), "optimizing" for optimization, "meanfield" for variational inference with independent normal distributions, or "fullrank" for variational inference with a multivariate normal distribution. See rstanarm-package for more details on the estimation algorithms. NOTE: not all fitting functions support all four algorithms.
adapt_delta	Only relevant if algorithm="sampling". See the adapt_delta help page for details.
QR	A logical scalar defaulting to FALSE, but if TRUE applies a scaled qr decomposition to the design matrix. The transformation does not change the likelihood of the data but is recommended for computational reasons when there are multiple predictors. See the QR-argument documentation page for details on how rstanarm does the transformation and important information about how to interpret the prior distributions of the model parameters when using QR=TRUE.
sparse	A logical scalar (defaulting to FALSE) indicating whether to use a sparse representation of the design (X) matrix. If TRUE, the the design matrix is not centered (since that would destroy the sparsity) and likewise it is not possible to specify both QR = TRUE and sparse = TRUE. Depending on how many zeros there are in the design matrix, setting sparse = TRUE may make the code run faster and can consume much less RAM.

Details

The `stan_clogit` function is mostly similar in syntax to `clogit` but rather than performing maximum likelihood estimation of generalized linear models, full Bayesian estimation is performed (if `algorithm` is "sampling") via MCMC. The Bayesian model adds priors (independent by default) on the coefficients of the GLM.

The `data.frame` passed to the `data` argument must be sorted by the variable passed to the `strata` argument.

The `formula` may have group-specific terms like in `stan_glm` but should not allow the intercept to vary by the stratifying variable, since there is no information in the data with which to estimate such deviations in the intercept.

Value

A `stanreg` object is returned for `stan_clogit`.

See Also

[stanreg-methods](#) and `clogit`.

The vignette for Bernoulli and binomial models, which has more details on using `stan_clogit`. <http://mc-stan.org/rstanarm/articles/>

Examples

```

dat <- infert[order(infert$stratum), ] # order by strata
post <- stan_clogit(case ~ spontaneous + induced + (1 | education),
  strata = stratum,
  data = dat,
  subset = parity <= 2,
  QR = TRUE,
  chains = 2, iter = 500) # for speed only

nd <- dat[dat$parity > 2, c("case", "spontaneous", "induced", "education", "stratum")]
# next line would fail without case and stratum variables
pr <- posterior_linpred(post, newdata = nd, transform = TRUE) # transform=TRUE gives probabilities

# not a random variable b/c probabilities add to 1 within strata
all.equal(rep(sum(nd$case), nrow(pr)), rowSums(pr))

```

stan_gamm4

Bayesian generalized linear additive models with optional group-specific terms via Stan

Description

Bayesian inference for GAMMs with flexible priors.

Usage

```

stan_gamm4(formula, random = NULL, family = gaussian(), data,
  weights = NULL, subset = NULL, na.action, knots = NULL,
  drop_unused_levels = TRUE, ..., prior = normal(),
  prior_intercept = normal(), prior_smooth = exponential(autoscale =
  FALSE), prior_aux = exponential(), prior_covariance = decov(),
  prior_PD = FALSE, algorithm = c("sampling", "meanfield", "fullrank"),
  adapt_delta = NULL, QR = FALSE, sparse = FALSE)

plot_nonlinear(x, smooths, ..., prob = 0.9, facet_args = list(),
  alpha = 1, size = 0.75)

```

Arguments

formula, random, family, data, knots, drop_unused_levels

Same as for [gamm4](#). *We strongly advise against omitting the data argument.* Unless data is specified (and is a data frame) many post-estimation functions (including update, loo, kfold) are not guaranteed to work properly.

subset, weights, na.action

Same as [glm](#), but rarely specified.

...

Further arguments passed to [sampling](#) (e.g. iter, chains, cores, etc.) or to [vb](#) (if algorithm is "meanfield" or "fullrank").

`prior` The prior distribution for the regression coefficients. `prior` should be a call to one of the various functions provided by **rstanarm** for specifying priors. The subset of these functions that can be used for the prior on the coefficients can be grouped into several "families":

Family	Functions
<i>Student t family</i>	normal, student_t, cauchy
<i>Hierarchical shrinkage family</i>	hs, hs_plus
<i>Laplace family</i>	laplace, lasso
<i>Product normal family</i>	product_normal

See the [priors help page](#) for details on the families and how to specify the arguments for all of the functions in the table above. To omit a prior —i.e., to use a flat (improper) uniform prior— `prior` can be set to `NULL`, although this is rarely a good idea.

Note: Unless `QR=TRUE`, if `prior` is from the Student t family or Laplace family, and if the `autoscale` argument to the function used to specify the prior (e.g. [normal](#)) is left at its default and recommended value of `TRUE`, then the default or user-specified prior scale(s) may be adjusted internally based on the scales of the predictors. See the [priors help page](#) and the *Prior Distributions* vignette for details on the rescaling and the [prior_summary](#) function for a summary of the priors used for a particular model.

`prior_intercept`

The prior distribution for the intercept. `prior_intercept` can be a call to `normal`, `student_t` or `cauchy`. See the [priors help page](#) for details on these functions. To omit a prior on the intercept —i.e., to use a flat (improper) uniform prior— `prior_intercept` can be set to `NULL`.

Note: If using a dense representation of the design matrix —i.e., if the `sparse` argument is left at its default value of `FALSE`— then the prior distribution for the intercept is set so it applies to the value *when all predictors are centered*. If you prefer to specify a prior on the intercept without the predictors being auto-centered, then you have to omit the intercept from the `formula` and include a column of ones as a predictor, in which case some element of `prior` specifies the prior on it, rather than `prior_intercept`. Regardless of how `prior_intercept` is specified, the reported *estimates* of the intercept always correspond to a parameterization without centered predictors (i.e., same as in `glm`).

`prior_smooth`

The prior distribution for the hyperparameters in GAMs, with lower values yielding less flexible smooth functions.

`prior_smooth` can be a call to `exponential` to use an exponential distribution, or `normal`, `student_t` or `cauchy`, which results in a half-normal, half-t, or half-Cauchy prior. See [priors](#) for details on these functions. To omit a prior —i.e., to use a flat (improper) uniform prior— set `prior_smooth` to `NULL`. The number of hyperparameters depends on the model specification but a scalar prior will be recycled as necessary to the appropriate length.

`prior_aux`

The prior distribution for the "auxiliary" parameter (if applicable). The "auxiliary" parameter refers to a different parameter depending on the family. For

Gaussian models `prior_aux` controls "sigma", the error standard deviation. For negative binomial models `prior_aux` controls "reciprocal_dispersion", which is similar to the "size" parameter of `rnbinom`: smaller values of "reciprocal_dispersion" correspond to greater dispersion. For gamma models `prior_aux` sets the prior on to the "shape" parameter (see e.g., `rgamma`), and for inverse-Gaussian models it is the so-called "lambda" parameter (which is essentially the reciprocal of a scale parameter). Binomial and Poisson models do not have auxiliary parameters.

`prior_aux` can be a call to `exponential` to use an exponential distribution, or `normal`, `student_t` or `cauchy`, which results in a half-normal, half-t, or half-Cauchy prior. See [priors](#) for details on these functions. To omit a prior —i.e., to use a flat (improper) uniform prior— set `prior_aux` to `NULL`.

<code>prior_covariance</code>	Cannot be <code>NULL</code> ; see decov for more information about the default arguments.
<code>prior_PD</code>	A logical scalar (defaulting to <code>FALSE</code>) indicating whether to draw from the prior predictive distribution instead of conditioning on the outcome.
<code>algorithm</code>	A string (possibly abbreviated) indicating the estimation approach to use. Can be "sampling" for MCMC (the default), "optimizing" for optimization, "meanfield" for variational inference with independent normal distributions, or "fullrank" for variational inference with a multivariate normal distribution. See rstanarm-package for more details on the estimation algorithms. NOTE: not all fitting functions support all four algorithms.
<code>adapt_delta</code>	Only relevant if <code>algorithm="sampling"</code> . See the adapt_delta help page for details.
<code>QR</code>	A logical scalar defaulting to <code>FALSE</code> , but if <code>TRUE</code> applies a scaled qr decomposition to the design matrix. The transformation does not change the likelihood of the data but is recommended for computational reasons when there are multiple predictors. See the QR-argument documentation page for details on how rstanarm does the transformation and important information about how to interpret the prior distributions of the model parameters when using <code>QR=TRUE</code> .
<code>sparse</code>	A logical scalar (defaulting to <code>FALSE</code>) indicating whether to use a sparse representation of the design (X) matrix. If <code>TRUE</code> , the the design matrix is not centered (since that would destroy the sparsity) and likewise it is not possible to specify both <code>QR = TRUE</code> and <code>sparse = TRUE</code> . Depending on how many zeros there are in the design matrix, setting <code>sparse = TRUE</code> may make the code run faster and can consume much less RAM.
<code>x</code>	An object produced by <code>stan_gamm4</code> .
<code>smooths</code>	An optional character vector specifying a subset of the smooth functions specified in the call to <code>stan_gamm4</code> . The default is include all smooth terms.
<code>prob</code>	For univariate smooths, a scalar between 0 and 1 governing the width of the uncertainty interval.
<code>facet_args</code>	An optional named list of arguments passed to facet_wrap (other than the <code>facets</code> argument).
<code>alpha, size</code>	For univariate smooths, passed to geom_ribbon . For bivariate smooths, <code>size/2</code> is passed to geom_contour .

Details

The `stan_gamm4` function is similar in syntax to `gamm4` in the **gamm4** package. But rather than performing (restricted) maximum likelihood estimation with the **lme4** package, the `stan_gamm4` function utilizes MCMC to perform Bayesian estimation. The Bayesian model adds priors on the common regression coefficients (in the same way as `stan_glm`), priors on the standard deviations of the smooth terms, and a prior on the decomposition of the covariance matrices of any group-specific parameters (as in `stan_glmer`). Estimating these models via MCMC avoids the optimization issues that often crop up with GAMMs and provides better estimates for the uncertainty in the parameter estimates.

See `gamm4` for more information about the model specification and `priors` for more information about the priors on the main coefficients. The formula should include at least one smooth term, which can be specified in any way that is supported by the `jagam` function in the **mgcv** package. The `prior_smooth` argument should be used to specify a prior on the unknown standard deviations that govern how smooth the smooth function is. The `prior_covariance` argument can be used to specify the prior on the components of the covariance matrix for any (optional) group-specific terms. The `gamm4` function in the **gamm4** package uses group-specific terms to implement the departure from linearity in the smooth terms, but that is not the case for `stan_gamm4` where the group-specific terms are exactly the same as in `stan_glmer`.

The `plot_nonlinear` function creates a `ggplot` object with one facet for each smooth function specified in the call to `stan_gamm4` in the case where all smooths are univariate. A subset of the smooth functions can be specified using the `smooths` argument, which is necessary to plot a bivariate smooth or to exclude the bivariate smooth and plot the univariate ones. In the bivariate case, a plot is produced using `geom_contour`. In the univariate case, the resulting plot is conceptually similar to `plot.gam` except the outer lines here demark the edges of posterior uncertainty intervals (credible intervals) rather than confidence intervals and the inner line is the posterior median of the function rather than the function implied by a point estimate. To change the colors used in the plot see `color_scheme_set`.

Value

A `stanreg` object is returned for `stan_gamm4`.

`plot_nonlinear` returns a `ggplot` object.

References

Crainiceanu, C., Ruppert D., and Wand, M. (2005). Bayesian analysis for penalized spline regression using WinBUGS. *Journal of Statistical Software*. **14**(14), 1–22. <https://www.jstatsoft.org/article/view/v014i14>

See Also

`stanreg-methods` and `gamm4`.

The vignette for `stan_glmer`, which also discusses `stan_gamm4`. <http://mc-stan.org/rstanarm/articles/>

Examples

```
# from example(gamm4, package = "gamm4"), prefixing gamm4() call with stan_

dat <- mgcv::gamSim(1, n = 400, scale = 2) ## simulate 4 term additive truth
## Now add 20 level random effect `fac`...
dat$fac <- fac <- as.factor(sample(1:20, 400, replace = TRUE))
dat$y <- dat$y + model.matrix(~ fac - 1) %*% rnorm(20) * .5

br <- stan_gamm4(y ~ s(x0) + x1 + s(x2), data = dat, random = ~ (1 | fac),
                chains = 1, iter = 200) # for example speed

print(br)
plot_nonlinear(br)
plot_nonlinear(br, smooths = "s(x0)", alpha = 2/3)
```

stan_glm

Bayesian generalized linear models via Stan

Description

Generalized linear modeling with optional prior distributions for the coefficients, intercept, and auxiliary parameters.

Usage

```
stan_glm(formula, family = gaussian(), data, weights, subset,
         na.action = NULL, offset = NULL, model = TRUE, x = FALSE,
         y = TRUE, contrasts = NULL, ..., prior = normal(),
         prior_intercept = normal(), prior_aux = exponential(),
         prior_PD = FALSE, algorithm = c("sampling", "optimizing",
         "meanfield", "fullrank"), mean_PPD = algorithm != "optimizing",
         adapt_delta = NULL, QR = FALSE, sparse = FALSE)

stan_glm.nb(formula, data, weights, subset, na.action = NULL,
            offset = NULL, model = TRUE, x = FALSE, y = TRUE,
            contrasts = NULL, link = "log", ..., prior = normal(),
            prior_intercept = normal(), prior_aux = exponential(),
            prior_PD = FALSE, algorithm = c("sampling", "optimizing",
            "meanfield", "fullrank"), mean_PPD = algorithm != "optimizing",
            adapt_delta = NULL, QR = FALSE)

stan_glm.fit(x, y, weights = rep(1, NROW(y)), offset = rep(0, NROW(y)),
            family = gaussian(), ..., prior = normal(),
            prior_intercept = normal(), prior_aux = exponential(),
            prior_smooth = exponential(autoscale = FALSE), prior_ops = NULL,
            group = list(), prior_PD = FALSE, algorithm = c("sampling",
            "optimizing", "meanfield", "fullrank"), mean_PPD = algorithm !=
            "optimizing", adapt_delta = NULL, QR = FALSE, sparse = FALSE)
```

Arguments

formula, data, subset	Same as glm , but <i>we strongly advise against omitting the data argument</i> . Unless data is specified (and is a data frame) many post-estimation functions (including update , loo , kfold) are not guaranteed to work properly.
family	Same as glm , except negative binomial GLMs are also possible using the neg_binomial_2 family object.
na.action, contrasts	Same as glm , but rarely specified.
model, offset, weights	Same as glm .
x	In stan_glm , logical scalar indicating whether to return the design matrix. In stan_glm.fit , usually a design matrix but can also be a list of design matrices with the same number of rows, in which case the first element of the list is interpreted as the primary design matrix and the remaining list elements collectively constitute a basis for a smooth nonlinear function of the predictors indicated by the formula argument to stan_gamm4 .
y	In stan_glm , logical scalar indicating whether to return the response vector. In stan_glm.fit , a response vector.
...	Further arguments passed to the function in the rstan package (sampling , vb , or optimizing), corresponding to the estimation method named by <code>algorithm</code> . For example, if <code>algorithm</code> is "sampling" it is possible to specify <code>iter</code> , <code>chains</code> , <code>cores</code> , <code>refresh</code> , etc.
prior	The prior distribution for the regression coefficients. <code>prior</code> should be a call to one of the various functions provided by rstanarm for specifying priors. The subset of these functions that can be used for the prior on the coefficients can be grouped into several "families":

Family	Functions
<i>Student t family</i>	<code>normal</code> , <code>student_t</code> , <code>cauchy</code>
<i>Hierarchical shrinkage family</i>	<code>hs</code> , <code>hs_plus</code>
<i>Laplace family</i>	<code>laplace</code> , <code>lasso</code>
<i>Product normal family</i>	<code>product_normal</code>

See the [priors help page](#) for details on the families and how to specify the arguments for all of the functions in the table above. To omit a prior—i.e., to use a flat (improper) uniform prior—`prior` can be set to `NULL`, although this is rarely a good idea.

Note: Unless `QR=TRUE`, if `prior` is from the Student t family or Laplace family, and if the `autoscale` argument to the function used to specify the prior (e.g. [normal](#)) is left at its default and recommended value of `TRUE`, then the default or user-specified prior scale(s) may be adjusted internally based on the scales of the predictors. See the [priors help page](#) and the *Prior Distributions* vignette for details on the rescaling and the [prior_summary](#) function for a summary of the priors used for a particular model.

prior_intercept	<p>The prior distribution for the intercept. <code>prior_intercept</code> can be a call to <code>normal</code>, <code>student_t</code> or <code>cauchy</code>. See the priors help page for details on these functions. To omit a prior on the intercept —i.e., to use a flat (improper) uniform prior— <code>prior_intercept</code> can be set to <code>NULL</code>.</p> <p>Note: If using a dense representation of the design matrix —i.e., if the <code>sparse</code> argument is left at its default value of <code>FALSE</code>— then the prior distribution for the intercept is set so it applies to the value <i>when all predictors are centered</i>. If you prefer to specify a prior on the intercept without the predictors being auto-centered, then you have to omit the intercept from the <code>formula</code> and include a column of ones as a predictor, in which case some element of <code>prior</code> specifies the prior on it, rather than <code>prior_intercept</code>. Regardless of how <code>prior_intercept</code> is specified, the reported <i>estimates</i> of the intercept always correspond to a parameterization without centered predictors (i.e., same as in <code>glm</code>).</p>
prior_aux	<p>The prior distribution for the "auxiliary" parameter (if applicable). The "auxiliary" parameter refers to a different parameter depending on the family. For Gaussian models <code>prior_aux</code> controls "sigma", the error standard deviation. For negative binomial models <code>prior_aux</code> controls "reciprocal_dispersion", which is similar to the "size" parameter of <code>rnbinom</code>: smaller values of "reciprocal_dispersion" correspond to greater dispersion. For gamma models <code>prior_aux</code> sets the prior on to the "shape" parameter (see e.g., rgamma), and for inverse-Gaussian models it is the so-called "lambda" parameter (which is essentially the reciprocal of a scale parameter). Binomial and Poisson models do not have auxiliary parameters.</p> <p><code>prior_aux</code> can be a call to <code>exponential</code> to use an exponential distribution, or <code>normal</code>, <code>student_t</code> or <code>cauchy</code>, which results in a half-normal, half-t, or half-Cauchy prior. See priors for details on these functions. To omit a prior —i.e., to use a flat (improper) uniform prior— set <code>prior_aux</code> to <code>NULL</code>.</p>
prior_PD	A logical scalar (defaulting to <code>FALSE</code>) indicating whether to draw from the prior predictive distribution instead of conditioning on the outcome.
algorithm	A string (possibly abbreviated) indicating the estimation approach to use. Can be "sampling" for MCMC (the default), "optimizing" for optimization, "meanfield" for variational inference with independent normal distributions, or "fullrank" for variational inference with a multivariate normal distribution. See rstanarm-package for more details on the estimation algorithms. NOTE: not all fitting functions support all four algorithms.
mean_PPD	A logical value indicating whether the sample mean of the posterior predictive distribution of the outcome should be calculated in the generated quantities block. If <code>TRUE</code> then <code>mean_PPD</code> is computed and displayed as a diagnostic in the printed output . The default is <code>TRUE</code> except if <code>algorithm=="optimizing"</code> . A useful heuristic is to check if <code>mean_PPD</code> is plausible when compared to <code>mean(y)</code> . If it is plausible then this does <i>not</i> mean that the model is good in general (only that it can reproduce the sample mean), but if <code>mean_PPD</code> is implausible then there may be something wrong, e.g., severe model misspecification, problems with the data and/or priors, computational issues, etc.
adapt_delta	Only relevant if <code>algorithm=="sampling"</code> . See the adapt_delta help page for details.

QR	A logical scalar defaulting to FALSE, but if TRUE applies a scaled qr decomposition to the design matrix. The transformation does not change the likelihood of the data but is recommended for computational reasons when there are multiple predictors. See the QR-argument documentation page for details on how rstanarm does the transformation and important information about how to interpret the prior distributions of the model parameters when using QR=TRUE.
sparse	A logical scalar (defaulting to FALSE) indicating whether to use a sparse representation of the design (X) matrix. If TRUE, the the design matrix is not centered (since that would destroy the sparsity) and likewise it is not possible to specify both QR = TRUE and sparse = TRUE. Depending on how many zeros there are in the design matrix, setting sparse = TRUE may make the code run faster and can consume much less RAM.
link	For stan_glm.nb only, the link function to use. See neg_binomial_2 .
prior_smooth	The prior distribution for the hyperparameters in GAMs, with lower values yielding less flexible smooth functions. prior_smooth can be a call to exponential to use an exponential distribution, or normal , student_t or cauchy , which results in a half-normal, half-t, or half-Cauchy prior. See priors for details on these functions. To omit a prior —i.e., to use a flat (improper) uniform prior— set prior_smooth to NULL. The number of hyperparameters depends on the model specification but a scalar prior will be recycled as necessary to the appropriate length.
prior_ops	Deprecated. See rstanarm-deprecated for details.
group	A list, possibly of length zero (the default), but otherwise having the structure of that produced by mkReTrms to indicate the group-specific part of the model. In addition, this list must have elements for the regularization, concentration shape, and scale components of a decov prior for the covariance matrices among the group-specific coefficients.

Details

The `stan_glm` function is similar in syntax to `glm` but rather than performing maximum likelihood estimation of generalized linear models, full Bayesian estimation is performed (if `algorithm` is "sampling") via MCMC. The Bayesian model adds priors (independent by default) on the coefficients of the GLM. The `stan_glm` function calls the workhorse `stan_glm.fit` function, but it is also possible to call the latter directly.

The `stan_glm.nb` function, which takes the extra argument `link`, is a wrapper for `stan_glm` with `family = neg_binomial_2(link)`.

Value

A `stanreg` object is returned for `stan_glm`, `stan_glm.nb`.

A `stanfit` object (or a slightly modified `stanfit` object) is returned if `stan_glm.fit` is called directly.

References

Gelman, A. and Hill, J. (2007). *Data Analysis Using Regression and Multilevel/Hierarchical Models*. Cambridge University Press, Cambridge, UK. (Ch. 3-6)

Muth, C., Oravecz, Z., and Gabry, J. (2018) User-friendly Bayesian regression modeling: A tutorial with rstanarm and shinystan. *The Quantitative Methods for Psychology*. 14(2), 99–119. <https://www.tqmp.org/RegularArticles/vol14-2/p099/p099.pdf>

See Also

[stanreg-methods](#) and [glm](#).

The various vignettes for `stan_glm` at <http://mc-stan.org/rstanarm/articles/>.

Examples

```
if (!grepl("^sparc", R.version$platform)) {
  ### Linear regression
  mtcars$mpg10 <- mtcars$mpg / 10
  fit <- stan_glm(
    mpg10 ~ wt + cyl + am,
    data = mtcars,
    QR = TRUE,
    # for speed of example only (default is "sampling")
    algorithm = "fullrank"
  )

  plot(fit, prob = 0.5)
  plot(fit, prob = 0.5, pars = "beta")
  plot(fit, "hist", pars = "sigma")
}

### Logistic regression
head(wells)
wells$dist100 <- wells$dist / 100
fit2 <- stan_glm(
  switch ~ dist100 + arsenic,
  data = wells,
  family = binomial(link = "logit"),
  prior_intercept = normal(0, 10),
  QR = TRUE,
  # for speed of example only
  chains = 2, iter = 200
)
print(fit2)
prior_summary(fit2)

# ?bayesplot::mcmc_areas
plot(fit2, plotfun = "areas", prob = 0.9,
     pars = c("Intercept", "arsenic"))

# ?bayesplot::ppc_error_binned
pp_check(fit2, plotfun = "error_binned")

### Poisson regression (example from help("glm"))
count_data <- data.frame(
```

```

counts = c(18,17,15,20,10,20,25,13,12),
outcome = gl(3,1,9),
treatment = gl(3,3)
)
fit3 <- stan_glm(
  counts ~ outcome + treatment,
  data = count_data,
  family = poisson(link="log"),
  prior = normal(0, 2, autoscale = FALSE),
  # for speed of example only
  chains = 2, iter = 250
)
print(fit3)

bayesplot::color_scheme_set("viridis")
plot(fit3)
plot(fit3, regex_pars = c("outcome", "treatment"))
plot(fit3, plotfun = "combo", regex_pars = "treatment") # ?bayesplot::mcmc_combo
posterior_vs_prior(fit3, regex_pars = c("outcome", "treatment"))

### Gamma regression (example from help("glm"))
clotting <- data.frame(log_u = log(c(5,10,15,20,30,40,60,80,100)),
  lot1 = c(118,58,42,35,27,25,21,19,18),
  lot2 = c(69,35,26,21,18,16,13,12,12))

fit4 <- stan_glm(
  lot1 ~ log_u,
  data = clotting,
  family = Gamma(link="log"),
  iter = 500 # for speed of example only
)
print(fit4, digits = 2)

fit5 <- update(fit4, formula = lot2 ~ log_u)

# ?bayesplot::ppc_dens_overlay
bayesplot::bayesplot_grid(
  pp_check(fit4, seed = 123),
  pp_check(fit5, seed = 123),
  titles = c("lot1", "lot2")
)

### Negative binomial regression
fit6 <- stan_glm.nb(Days ~ Sex/(Age + Eth*Lrn), data = MASS::quine,
  link = "log", prior_aux = exponential(1.5),
  chains = 2, iter = 200) # for speed of example only

prior_summary(fit6)
bayesplot::color_scheme_set("brightblue")
plot(fit6)
pp_check(fit6, plotfun = "hist", nreps = 5) # ?bayesplot::ppc_hist

# 80% interval of estimated reciprocal_dispersion parameter

```

```
posterior_interval(fit6, pars = "reciprocal_dispersion", prob = 0.8)
plot(fit6, "areas", pars = "reciprocal_dispersion", prob = 0.8)
```

 stan_glmer

Bayesian generalized linear models with group-specific terms via Stan

Description

Bayesian inference for GLMs with group-specific coefficients that have unknown covariance matrices with flexible priors.

Usage

```
stan_glmer(formula, data = NULL, family = gaussian, subset, weights,
  na.action = getOption("na.action", "na.omit"), offset,
  contrasts = NULL, ..., prior = normal(),
  prior_intercept = normal(), prior_aux = exponential(),
  prior_covariance = decov(), prior_PD = FALSE,
  algorithm = c("sampling", "meanfield", "fullrank"),
  adapt_delta = NULL, QR = FALSE, sparse = FALSE)
```

```
stan_lmer(formula, data = NULL, subset, weights,
  na.action = getOption("na.action", "na.omit"), offset,
  contrasts = NULL, ..., prior = normal(),
  prior_intercept = normal(), prior_aux = exponential(),
  prior_covariance = decov(), prior_PD = FALSE,
  algorithm = c("sampling", "meanfield", "fullrank"),
  adapt_delta = NULL, QR = FALSE)
```

```
stan_glmer.nb(formula, data = NULL, subset, weights,
  na.action = getOption("na.action", "na.omit"), offset,
  contrasts = NULL, link = "log", ..., prior = normal(),
  prior_intercept = normal(), prior_aux = exponential(),
  prior_covariance = decov(), prior_PD = FALSE,
  algorithm = c("sampling", "meanfield", "fullrank"),
  adapt_delta = NULL, QR = FALSE)
```

Arguments

formula, data	Same as for glmer . <i>We strongly advise against omitting the data argument.</i> Unless data is specified (and is a data frame) many post-estimation functions (including update, loo, kfold) are not guaranteed to work properly.
family	Same as for glmer except it is also possible to use family=mgcv::betar to estimate a Beta regression with stan_glmer.

subset, weights, offset	Same as glm .
na.action, contrasts	Same as glm , but rarely specified.
...	For <code>stan_glmr</code> , further arguments passed to sampling (e.g. <code>iter</code> , <code>chains</code> , <code>cores</code> , etc.) or to <code>vb</code> (if algorithm is "meanfield" or "fullrank"). For <code>stan_lmer</code> and <code>stan_glmr.nb</code> , ... should also contain all relevant arguments to pass to <code>stan_glmr</code> (except <code>family</code>).
prior	The prior distribution for the regression coefficients. <code>prior</code> should be a call to one of the various functions provided by rstanarm for specifying priors. The subset of these functions that can be used for the prior on the coefficients can be grouped into several "families":

Family	Functions
<i>Student t family</i>	<code>normal</code> , <code>student_t</code> , <code>cauchy</code>
<i>Hierarchical shrinkage family</i>	<code>hs</code> , <code>hs_plus</code>
<i>Laplace family</i>	<code>laplace</code> , <code>lasso</code>
<i>Product normal family</i>	<code>product_normal</code>

See the [priors help page](#) for details on the families and how to specify the arguments for all of the functions in the table above. To omit a prior —i.e., to use a flat (improper) uniform prior— `prior` can be set to `NULL`, although this is rarely a good idea.

Note: Unless `QR=TRUE`, if `prior` is from the Student t family or Laplace family, and if the `autoscale` argument to the function used to specify the prior (e.g. [normal](#)) is left at its default and recommended value of `TRUE`, then the default or user-specified prior scale(s) may be adjusted internally based on the scales of the predictors. See the [priors help page](#) and the *Prior Distributions* vignette for details on the rescaling and the [prior_summary](#) function for a summary of the priors used for a particular model.

prior_intercept	The prior distribution for the intercept. <code>prior_intercept</code> can be a call to <code>normal</code> , <code>student_t</code> or <code>cauchy</code> . See the priors help page for details on these functions. To omit a prior on the intercept —i.e., to use a flat (improper) uniform prior— <code>prior_intercept</code> can be set to <code>NULL</code> . Note: If using a dense representation of the design matrix —i.e., if the <code>sparse</code> argument is left at its default value of <code>FALSE</code> — then the prior distribution for the intercept is set so it applies to the value <i>when all predictors are centered</i> . If you prefer to specify a prior on the intercept without the predictors being auto-centered, then you have to omit the intercept from the formula and include a column of ones as a predictor, in which case some element of <code>prior</code> specifies the prior on it, rather than <code>prior_intercept</code> . Regardless of how <code>prior_intercept</code> is specified, the reported <i>estimates</i> of the intercept always correspond to a parameterization without centered predictors (i.e., same as in <code>glm</code>).
prior_aux	The prior distribution for the "auxiliary" parameter (if applicable). The "auxiliary" parameter refers to a different parameter depending on the family. For

Gaussian models `prior_aux` controls "sigma", the error standard deviation. For negative binomial models `prior_aux` controls "reciprocal_dispersion", which is similar to the "size" parameter of `rnbinom`: smaller values of "reciprocal_dispersion" correspond to greater dispersion. For gamma models `prior_aux` sets the prior on to the "shape" parameter (see e.g., `rgamma`), and for inverse-Gaussian models it is the so-called "lambda" parameter (which is essentially the reciprocal of a scale parameter). Binomial and Poisson models do not have auxiliary parameters.

`prior_aux` can be a call to `exponential` to use an exponential distribution, or `normal`, `student_t` or `cauchy`, which results in a half-normal, half-t, or half-Cauchy prior. See [priors](#) for details on these functions. To omit a prior —i.e., to use a flat (improper) uniform prior— set `prior_aux` to `NULL`.

<code>prior_covariance</code>	Cannot be <code>NULL</code> ; see decov for more information about the default arguments.
<code>prior_PD</code>	A logical scalar (defaulting to <code>FALSE</code>) indicating whether to draw from the prior predictive distribution instead of conditioning on the outcome.
<code>algorithm</code>	A string (possibly abbreviated) indicating the estimation approach to use. Can be "sampling" for MCMC (the default), "optimizing" for optimization, "meanfield" for variational inference with independent normal distributions, or "fullrank" for variational inference with a multivariate normal distribution. See rstanarm-package for more details on the estimation algorithms. NOTE: not all fitting functions support all four algorithms.
<code>adapt_delta</code>	Only relevant if <code>algorithm="sampling"</code> . See the adapt_delta help page for details.
<code>QR</code>	A logical scalar defaulting to <code>FALSE</code> , but if <code>TRUE</code> applies a scaled qr decomposition to the design matrix. The transformation does not change the likelihood of the data but is recommended for computational reasons when there are multiple predictors. See the QR-argument documentation page for details on how rstanarm does the transformation and important information about how to interpret the prior distributions of the model parameters when using <code>QR=TRUE</code> .
<code>sparse</code>	A logical scalar (defaulting to <code>FALSE</code>) indicating whether to use a sparse representation of the design (X) matrix. If <code>TRUE</code> , the the design matrix is not centered (since that would destroy the sparsity) and likewise it is not possible to specify both <code>QR = TRUE</code> and <code>sparse = TRUE</code> . Depending on how many zeros there are in the design matrix, setting <code>sparse = TRUE</code> may make the code run faster and can consume much less RAM.
<code>link</code>	For <code>stan_glmer.nb</code> only, the link function to use. See neg_binomial_2 .

Details

The `stan_glmer` function is similar in syntax to [glmer](#) but rather than performing (restricted) maximum likelihood estimation of generalized linear models, Bayesian estimation is performed via MCMC. The Bayesian model adds priors on the regression coefficients (in the same way as [stan_glm](#)) and priors on the terms of a decomposition of the covariance matrices of the group-specific parameters. See [priors](#) for more information about the priors.

The `stan_lmer` function is equivalent to `stan_glmer` with `family = gaussian(link = "identity")`.

The `stan_glmr.nb` function, which takes the extra argument `link`, is a wrapper for `stan_glmr` with `family = neg_binomial_2(link)`.

Value

A `stanreg` object is returned for `stan_glmr`, `stan_lmer`, `stan_glmr.nb`.

References

Gelman, A. and Hill, J. (2007). *Data Analysis Using Regression and Multilevel/Hierarchical Models*. Cambridge University Press, Cambridge, UK. (Ch. 11-15)

Muth, C., Oravecz, Z., and Gabry, J. (2018) User-friendly Bayesian regression modeling: A tutorial with `rstanarm` and `shinystan`. *The Quantitative Methods for Psychology*. 14(2), 99–119. <https://www.tqmp.org/RegularArticles/vol14-2/p099/p099.pdf>

See Also

[stanreg-methods](#) and [glmr](#).

The vignette for `stan_glmr` and the *Hierarchical Partial Pooling* vignette. <http://mc-stan.org/rstanarm/articles/>

Examples

```
# see help(example_model) for details on the model below
if (!exists("example_model")) example(example_model)
print(example_model, digits = 1)
```

stan_jm

Bayesian joint longitudinal and time-to-event models via Stan

Description

Fits a shared parameter joint model for longitudinal and time-to-event (e.g. survival) data under a Bayesian framework using Stan.

Usage

```
stan_jm(formulaLong, dataLong, formulaEvent, dataEvent, time_var, id_var,
  family = gaussian, assoc = "etavalue", lag_assoc = 0, grp_assoc,
  epsilon = 1e-05, basehaz = c("bs", "weibull", "piecewise"),
  basehaz_ops, qnodes = 15, init = "prefit", weights,
  priorLong = normal(), priorLong_intercept = normal(),
  priorLong_aux = cauchy(0, 5), priorEvent = normal(),
  priorEvent_intercept = normal(), priorEvent_aux = cauchy(),
  priorEvent_assoc = normal(), prior_covariance = lkj(),
  prior_PD = FALSE, algorithm = c("sampling", "meanfield", "fullrank"),
  adapt_delta = NULL, max_treedepth = 10L, QR = FALSE,
  sparse = FALSE, ...)
```

Arguments

formulaLong	A two-sided linear formula object describing both the fixed-effects and random-effects parts of the longitudinal submodel, similar in vein to formula specification in the lme4 package (see glmer or the lme4 vignette for details). Note however that the double bar () notation is not allowed when specifying the random-effects parts of the formula, and neither are nested grouping factors (e.g. (1 g1/g2)) or (1 g1:g2), where g1, g2 are grouping factors. For a multivariate joint model (i.e. more than one longitudinal marker) this should be a list of such formula objects, with each element of the list providing the formula for one of the longitudinal submodels.
dataLong	A data frame containing the variables specified in formulaLong. If fitting a multivariate joint model, then this can be either a single data frame which contains the data for all longitudinal submodels, or it can be a list of data frames where each element of the list provides the data for one of the longitudinal submodels.
formulaEvent	A two-sided formula object describing the event submodel. The left hand side of the formula should be a Surv() object. See Surv .
dataEvent	A data frame containing the variables specified in formulaEvent.
time_var	A character string specifying the name of the variable in dataLong which represents time.
id_var	A character string specifying the name of the variable in dataLong which distinguishes between individuals. This can be left unspecified if there is only one grouping factor (which is assumed to be the individual). If there is more than one grouping factor (i.e. clustering beyond the level of the individual) then the id_var argument must be specified.
family	The family (and possibly also the link function) for the longitudinal submodel(s). See glmer for details. If fitting a multivariate joint model, then this can optionally be a list of families, in which case each element of the list specifies the family for one of the longitudinal submodels.
assoc	A character string or character vector specifying the joint model association structure. Possible association structures that can be used include: "etavalue" (the default); "etaslope"; "etaauc"; "muvalue"; "muslope"; "muauc"; "shared_b"; "shared_coef"; or "null". These are described in the Details section below. For a multivariate joint model, different association structures can optionally be used for each longitudinal submodel by specifying a list of character vectors, with each element of the list specifying the desired association structure for one of the longitudinal submodels. Specifying assoc = NULL will fit a joint model with no association structure (equivalent to fitting separate longitudinal and time-to-event models). It is also possible to include interaction terms between the association term ("etavalue", "etaslope", "muvalue", "muslope") and observed data/covariates. It is also possible, when fitting a multivariate joint model, to include interaction terms between the association terms ("etavalue" or "muvalue") corresponding to the different longitudinal outcomes. See the Details section as well as the Examples below.
lag_assoc	A non-negative scalar specifying the time lag that should be used for the association structure. That is, the hazard of the event at time t will be assumed to be associated with the value/slope/auc of the longitudinal marker at time $t-u$,

where u is the time lag. If fitting a multivariate joint model, then a different time lag can be used for each longitudinal marker by providing a numeric vector of lags, otherwise if a scalar is provided then the specified time lag will be used for all longitudinal markers. Note however that only one time lag can be specified for linking each longitudinal marker to the event, and that that time lag will be used for all association structure types (e.g. "etavalue", "etaslope", "etaauc", "muvalue", etc) that are specified for that longitudinal marker in the `assoc` argument.

<code>grp_assoc</code>	Character string specifying the method for combining information across lower level units clustered within an individual when forming the association structure. This is only relevant when a grouping factor is specified in <code>formulaLong</code> that corresponds to clustering within individuals. This can be specified as either "sum", mean, "min" or "max". For example, specifying <code>grp_assoc = "sum"</code> indicates that the association structure should be based on a summation across the lower level units clustered within an individual, or specifying <code>grp_assoc = "mean"</code> indicates that the association structure should be based on the mean (i.e. average) taken across the lower level units clustered within an individual. So, for example, specifying <code>assoc = "muvalue"</code> and <code>grp_assoc = "sum"</code> would mean that the log hazard at time t for individual i would be linearly related to the sum of the expected values at time t for each of the lower level units (which may be for example tumor lesions) clustered within that individual.
<code>epsilon</code>	The half-width of the central difference used to numerically calculate the derivate when the "etaslope" association structure is used.
<code>basehaz</code>	A character string indicating which baseline hazard to use for the event sub-model. Options are a B-splines approximation estimated for the log baseline hazard ("bs", the default), a Weibull baseline hazard ("weibull", the default), or a piecewise constant baseline hazard ("piecewise"). (Note however that there is currently limited post-estimation functionality available for models estimated using a piecewise constant baseline hazard).
<code>basehaz_ops</code>	A named list specifying options related to the baseline hazard. Currently this can include: <ul style="list-style-type: none"> <code>df</code> A positive integer specifying the degrees of freedom for the B-splines if <code>basehaz = "bs"</code>, or the number of intervals used for the piecewise constant baseline hazard if <code>basehaz = "piecewise"</code>. The default is 6. <code>knots</code> An optional numeric vector specifying the internal knot locations for the B-splines if <code>basehaz = "bs"</code>, or the internal cut-points for defining intervals of the piecewise constant baseline hazard if <code>basehaz = "piecewise"</code>. Knots cannot be specified if <code>df</code> is specified. If not specified, then the default is to use <code>df - 4</code> knots if <code>basehaz = "bs"</code>, or <code>df - 1</code> knots if <code>basehaz = "piecewise"</code>, which are placed at equally spaced percentiles of the distribution of observed event times.
<code>qnodes</code>	The number of nodes to use for the Gauss-Kronrod quadrature that is used to evaluate the cumulative hazard in the likelihood function. Options are 15 (the default), 11 or 7.
<code>init</code>	The method for generating the initial values for the MCMC. The default is "prefit", which uses those obtained from fitting separate longitudinal and

time-to-event models prior to fitting the joint model. The separate longitudinal model is a (possibly multivariate) generalised linear mixed model estimated using variational bayes. This is achieved via the `stan_mvmer` function with `algorithm = "meanfield"`. The separate Cox model is estimated using `coxph`. This is achieved using the and time-to-event models prior to fitting the joint model. The separate models are estimated using the `glmer` and `coxph` functions. This should provide reasonable initial values which should aid the MCMC sampler. Parameters that cannot be obtained from fitting separate longitudinal and time-to-event models are initialised using the "random" method for `stan`. However it is recommended that any final analysis should ideally be performed with several MCMC chains each initiated from a different set of initial values; this can be obtained by setting `init = "random"`. In addition, other possibilities for specifying `init` are the same as those described for `stan`.

`weights` Experimental and should be used with caution. The user can optionally supply a 2-column data frame containing a set of 'prior weights' to be used in the estimation process. The data frame should contain two columns: the first containing the IDs for each individual, and the second containing the corresponding weights. The data frame should only have one row for each individual; that is, weights should be constant within individuals.

`priorLong`, `priorEvent`, `priorEvent_assoc`

The prior distributions for the regression coefficients in the longitudinal submodel(s), event submodel, and the association parameter(s). Can be a call to one of the various functions provided by `rstanarm` for specifying priors. The subset of these functions that can be used for the prior on the coefficients can be grouped into several "families":

Family	Functions
<i>Student t family</i>	<code>normal</code> , <code>student_t</code> , <code>cauchy</code>
<i>Hierarchical shrinkage family</i>	<code>hs</code> , <code>hs_plus</code>
<i>Laplace family</i>	<code>laplace</code> , <code>lasso</code>

See the [priors help page](#) for details on the families and how to specify the arguments for all of the functions in the table above. To omit a prior—i.e., to use a flat (improper) uniform prior—`prior` can be set to `NULL`, although this is rarely a good idea.

Note: Unless `QR=TRUE`, if `prior` is from the Student t family or Laplace family, and if the `autoscale` argument to the function used to specify the prior (e.g. `normal`) is left at its default and recommended value of `TRUE`, then the default or user-specified prior scale(s) may be adjusted internally based on the scales of the predictors. See the [priors help page](#) for details on the rescaling and the `prior_summary` function for a summary of the priors used for a particular model.

`priorLong_intercept`, `priorEvent_intercept`

The prior distributions for the intercepts in the longitudinal submodel(s) and event submodel. Can be a call to `normal`, `student_t` or `cauchy`. See the [priors help page](#) for details on these functions. To omit a prior on the intercept—i.e., to use a flat (improper) uniform prior—`prior_intercept` can be set to `NULL`.

Note: The prior distribution for the intercept is set so it applies to the value when all predictors are centered. Moreover, note that a prior is only placed on the intercept for the event submodel when a Weibull baseline hazard has been specified. For the B-splines and piecewise constant baseline hazards there is not intercept parameter that is given a prior distribution; an intercept parameter will be shown in the output for the fitted model, but this just corresponds to the necessary post-estimation adjustment in the linear predictor due to the centering of the predictions in the event submodel.

- `priorLong_aux` The prior distribution for the "auxiliary" parameters in the longitudinal submodels (if applicable). The "auxiliary" parameter refers to a different parameter depending on the family. For Gaussian models `priorLong_aux` controls "sigma", the error standard deviation. For negative binomial models `priorLong_aux` controls "reciprocal_dispersion", which is similar to the "size" parameter of `rnbinom`: smaller values of "reciprocal_dispersion" correspond to greater dispersion. For gamma models `priorLong_aux` sets the prior on to the "shape" parameter (see e.g., `rgamma`), and for inverse-Gaussian models it is the so-called "lambda" parameter (which is essentially the reciprocal of a scale parameter). Binomial and Poisson models do not have auxiliary parameters.
- `priorLong_aux` can be a call to `exponential` to use an exponential distribution, or `normal`, `student_t` or `cauchy`, which results in a half-normal, half-t, or half-Cauchy prior. See [priors](#) for details on these functions. To omit a prior —i.e., to use a flat (improper) uniform prior— set `priorLong_aux` to `NULL`.
- If fitting a multivariate joint model, you have the option to specify a list of prior distributions, however the elements of the list that correspond to any longitudinal submodel which does not have an auxiliary parameter will be ignored.
- `priorEvent_aux` The prior distribution for the "auxiliary" parameters in the event submodel. The "auxiliary" parameters refers to different parameters depending on the baseline hazard. For `basehaz = "weibull"` the auxiliary parameter is the Weibull shape parameter. For `basehaz = "bs"` the auxiliary parameters are the coefficients for the B-spline approximation to the log baseline hazard. For `basehaz = "piecewise"` the auxiliary parameters are the piecewise estimates of the log baseline hazard.
- `prior_covariance` Cannot be `NULL`; see [priors](#) for more information about the prior distributions on covariance matrices. Note however that the default prior for covariance matrices in `stan_jm` is slightly different to that in `stan_glmr` (the details of which are described on the [priors](#) page).
- `prior_PD` A logical scalar (defaulting to `FALSE`) indicating whether to draw from the prior predictive distribution instead of conditioning on the outcome.
- `algorithm` A string (possibly abbreviated) indicating the estimation approach to use. Can be "sampling" for MCMC (the default), "optimizing" for optimization, "meanfield" for variational inference with independent normal distributions, or "fullrank" for variational inference with a multivariate normal distribution. See [rstanarm-package](#) for more details on the estimation algorithms. NOTE: not all fitting functions support all four algorithms.
- `adapt_delta` Only relevant if `algorithm="sampling"`. See the [adapt_delta](#) help page for details.

max_treedepth	A positive integer specifying the maximum treedepth for the non-U-turn sampler. See the <code>control</code> argument in <code>stan</code> .
QR	A logical scalar defaulting to FALSE, but if TRUE applies a scaled <code>qr</code> decomposition to the design matrix. The transformation does not change the likelihood of the data but is recommended for computational reasons when there are multiple predictors. See the QR-argument documentation page for details on how <code>rstanarm</code> does the transformation and important information about how to interpret the prior distributions of the model parameters when using <code>QR=TRUE</code> .
sparse	A logical scalar (defaulting to FALSE) indicating whether to use a sparse representation of the design (X) matrix. If TRUE, the the design matrix is not centered (since that would destroy the sparsity) and likewise it is not possible to specify both <code>QR = TRUE</code> and <code>sparse = TRUE</code> . Depending on how many zeros there are in the design matrix, setting <code>sparse = TRUE</code> may make the code run faster and can consume much less RAM.
...	Further arguments passed to the function in the <code>rstan</code> package (<code>sampling</code> , <code>vb</code> , or <code>optimizing</code>), corresponding to the estimation method named by <code>algorithm</code> . For example, if <code>algorithm</code> is "sampling" it is possible to specify <code>iter</code> , <code>chains</code> , <code>cores</code> , <code>refresh</code> , etc.

Details

The `stan_jm` function can be used to fit a joint model (also known as a shared parameter model) for longitudinal and time-to-event data under a Bayesian framework. The underlying estimation is carried out using the Bayesian C++ package Stan (<http://mc-stan.org/>).

The joint model may be univariate (with only one longitudinal submodel) or multivariate (with more than one longitudinal submodel). For the longitudinal submodel a (possibly multivariate) generalised linear mixed model is assumed with any of the `family` choices allowed by `glmer`. If a multivariate joint model is specified (by providing a list of formulas in the `formulaLong` argument), then the multivariate longitudinal submodel consists of a multivariate generalized linear model (GLM) with group-specific terms that are assumed to be correlated across the different GLM submodels. That is, within a grouping factor (for example, patient ID) the group-specific terms are assumed to be correlated across the different GLM submodels. It is possible to specify a different outcome type (for example a different family and/or link function) for each of the GLM submodels, by providing a list of `family` objects in the `family` argument. Multi-level clustered data are allowed, and that additional clustering can occur at a level higher than the individual-level (e.g. patients clustered within clinics), or at a level lower than the individual-level (e.g. tumor lesions clustered within patients). If the clustering occurs at a level lower than the individual, then the user needs to indicate how the lower level clusters should be handled when forming the association structure between the longitudinal and event submodels (see the `grp_assoc` argument described above).

For the event submodel a parametric proportional hazards model is assumed. The baseline hazard can be estimated using either a cubic B-splines approximation (`basehaz = "bs"`, the default), a Weibull distribution (`basehaz = "weibull"`), or a piecewise constant baseline hazard (`basehaz = "piecewise"`). If the B-spline or piecewise constant baseline hazards are used, then the degrees of freedom or the internal knot locations can be (optionally) specified. If the degrees of freedom are specified (through the `df` argument) then the knot locations are automatically generated

based on the distribution of the observed event times (not including censoring times). Otherwise internal knot locations can be specified directly through the `knots` argument. If neither `df` or `knots` is specified, then the default is to set `df` equal to 6. It is not possible to specify both `df` and `knots`.

Time-varying covariates are allowed in both the longitudinal and event submodels. These should be specified in the data in the same way as they normally would when fitting a separate longitudinal model using `lmer` or a separate time-to-event model using `coxph`. These time-varying covariates should be exogenous in nature, otherwise they would perhaps be better specified as an additional outcome (i.e. by including them as an additional longitudinal outcome in the joint model).

Bayesian estimation of the joint model is performed via MCMC. The Bayesian model includes independent priors on the regression coefficients for both the longitudinal and event submodels, including the association parameter(s) (in much the same way as the regression parameters in `stan_glm`) and priors on the terms of a decomposition of the covariance matrices of the group-specific parameters. See `priors` for more information about the priors distributions that are available.

Gauss-Kronrod quadrature is used to numerically evaluate the integral over the cumulative hazard in the likelihood function for the event submodel. The accuracy of the numerical approximation can be controlled using the number of quadrature nodes, specified through the `qnodes` argument. Using a higher number of quadrature nodes will result in a more accurate approximation.

Association structures: The association structure for the joint model can be based on any of the following parameterisations:

- current value of the linear predictor in the longitudinal submodel (`"etavalue"`)
- first derivative (slope) of the linear predictor in the longitudinal submodel (`"etaslope"`)
- the area under the curve of the linear predictor in the longitudinal submodel (`"etaauc"`)
- current expected value of the longitudinal submodel (`"muvalue"`)
- the area under the curve of the expected value from the longitudinal submodel (`"muauc"`)
- shared individual-level random effects (`"shared_b"`)
- shared individual-level random effects which also incorporate the corresponding fixed effect as well as any corresponding random effects for clustering levels higher than the individual (`"shared_coef"`)
- interactions between association terms and observed data/covariates (`"etavalue_data"`, `"etaslope_data"`, `"muvalue_data"`, `"muslope_data"`). These are described further below.
- interactions between association terms corresponding to different longitudinal outcomes in a multivariate joint model (`"etavalue_etavalue(#)"`, `"etavalue_muvalue(#)"`, `"muvalue_etavalue(#)"`, `"muvalue_muvalue(#)"`). These are described further below.
- no association structure (equivalent to fitting separate longitudinal and event models) (`"null"` or `NULL`)

More than one association structure can be specified, however, not all possible combinations are allowed. Note that for the lagged association structures baseline values (time = 0) are used for the instances where the time lag results in a time prior to baseline. When using the `"etaauc"` or `"muauc"` association structures, the area under the curve is evaluated using Gauss-Kronrod quadrature with 15 quadrature nodes. By default, `"shared_b"` and `"shared_coef"` contribute all random effects to the association structure; however, a subset of the random effects can be chosen by specifying their indices between parentheses as a suffix, for example, `"shared_b(1)"` or `"shared_b(1:3)"` or `"shared_b(1,2,4)"`, and so on.

In addition, several association terms ("etavalue", "etaslope", "muvalue", "muslope") can be interacted with observed data/covariates. To do this, use the association term's main handle plus a suffix of "_data" then followed by the model matrix formula in parentheses. For example if we had a variable in our dataset for gender named sex then we might want to obtain different estimates for the association between the current slope of the marker and the risk of the event for each gender. To do this we would specify `assoc = c("etaslope", "etaslope_data(~ sex)")`.

It is also possible, when fitting a multivariate joint model, to include interaction terms between the association terms themselves (this only applies for interacting "etavalue" or "muvalue"). For example, if we had a joint model with two longitudinal markers, we could specify `assoc = list(c("etavalue", "etaval", "muvalue", "muslope", "muvalue_data(~ marker2)", "muslope_data(~ marker2)"))`. The first element of list says we want to use the value of the linear predictor for the first marker, as well as it's interaction with the value of the linear predictor for the second marker. The second element of the list says we want to also include the expected value of the second marker (i.e. as a "main effect"). Therefore, the linear predictor for the event submodel would include the "main effects" for each marker as well as their interaction.

There are additional examples in the **Examples** section below.

Value

A `stanjm` object is returned.

See Also

[stanreg-objects](#), [stanmvreg-methods](#), [print.stanmvreg](#), [summary.stanmvreg](#), [posterior_traj](#), [posterior_survfit](#), [posterior_predict](#), [posterior_interval](#), [pp_check](#), [ps_check](#), [stan_mvmer](#).

Examples

```
#####
# Univariate joint model, with association structure based on the
# current value of the linear predictor
f1 <- stan_jm(formulaLong = logBili ~ year + (1 | id),
              dataLong = pbcLong,
              formulaEvent = Surv(futimeYears, death) ~ sex + trt,
              dataEvent = pbcSurv,
              time_var = "year",
              # this next line is only to keep the example small in size!
              chains = 1, cores = 1, seed = 12345, iter = 1000)

print(f1)
summary(f1)

#####
# Univariate joint model, with association structure based on the
# current value and slope of the linear predictor
f2 <- stan_jm(formulaLong = logBili ~ year + (year | id),
              dataLong = pbcLong,
              formulaEvent = Surv(futimeYears, death) ~ sex + trt,
              dataEvent = pbcSurv,
```

```

    assoc = c("etavalue", "etaslope"),
    time_var = "year",
    chains = 1, cores = 1, seed = 12345, iter = 1000)
print(f2)

#####
# Univariate joint model, with association structure based on the
# lagged value of the linear predictor, where the lag is 2 time
# units (i.e. 2 years in this example)
f3 <- stan_jm(formulaLong = logBili ~ year + (1 | id),
              dataLong = pbcLong,
              formulaEvent = Surv(futimeYears, death) ~ sex + trt,
              dataEvent = pbcSurv,
              time_var = "year",
              assoc = "etavalue", lag_assoc = 2,
              chains = 1, cores = 1, seed = 12345, iter = 1000)
print(f3)

#####
# Univariate joint model, where the association structure includes
# interactions with observed data. Here we specify that we want to use
# an association structure based on the current value of the linear
# predictor from the longitudinal submodel (i.e. "etavalue"), but we
# also want to interact this with the treatment covariate (trt) from
# pbcLong data frame, so that we can estimate a different association
# parameter (i.e. estimated effect of log serum bilirubin on the log
# hazard of death) for each treatment group
f4 <- stan_jm(formulaLong = logBili ~ year + (1 | id),
              dataLong = pbcLong,
              formulaEvent = Surv(futimeYears, death) ~ sex + trt,
              dataEvent = pbcSurv,
              time_var = "year",
              assoc = c("etavalue", "etavalue_data(~ trt)"),
              chains = 1, cores = 1, seed = 12345, iter = 1000)
print(f4)

#####
# Multivariate joint model, with association structure based
# on the current value and slope of the linear predictor in the
# first longitudinal submodel and the area under the marker
# trajectory for the second longitudinal submodel
mv1 <- stan_jm(
  formulaLong = list(
    logBili ~ year + (1 | id),
    albumin ~ sex + year + (year | id)),
  dataLong = pbcLong,
  formulaEvent = Surv(futimeYears, death) ~ sex + trt,
  dataEvent = pbcSurv,
  assoc = list(c("etavalue", "etaslope"), "etaauc"),
  time_var = "year",
  chains = 1, cores = 1, seed = 12345, iter = 100)
print(mv1)

```

```
#####
# Multivariate joint model, where the association structure is formed by
# including the expected value of each longitudinal marker (logBili and
# albumin) in the linear predictor of the event submodel, as well as their
# interaction effect (i.e. the interaction between the two "etavalue" terms).
# Note that whether such an association structure based on a marker by
# marker interaction term makes sense will depend on the context of your
# application -- here we just show it for demonstration purposes).
mv2 <- stan_jm(
  formulaLong = list(
    logBili ~ year + (1 | id),
    albumin ~ sex + year + (year | id)),
  dataLong = pbcLong,
  formulaEvent = Surv(futimeYears, death) ~ sex + trt,
  dataEvent = pbcSurv,
  assoc = list(c("etavalue", "etavalue_etavalue(2)", "etavalue"),
    time_var = "year",
  chains = 1, cores = 1, seed = 12345, iter = 100)

#####
# Multivariate joint model, with one bernoulli marker and one
# Gaussian marker. We will artificially create the bernoulli
# marker by dichotomising log serum bilirubin
pbcLong$ybern <- as.integer(pbcLong$logBili >= mean(pbcLong$logBili))
mv3 <- stan_jm(
  formulaLong = list(
    ybern ~ year + (1 | id),
    albumin ~ sex + year + (year | id)),
  dataLong = pbcLong,
  formulaEvent = Surv(futimeYears, death) ~ sex + trt,
  dataEvent = pbcSurv,
  family = list(binomial, gaussian),
  time_var = "year",
  chains = 1, cores = 1, seed = 12345, iter = 1000)
```

stan_mvmer

*Bayesian multivariate generalized linear models with correlated
group-specific terms via Stan*

Description

Bayesian inference for multivariate GLMs with group-specific coefficients that are assumed to be correlated across the GLM submodels.

Usage

```
stan_mvmer(formula, data, family = gaussian, weights, prior = normal(),
  prior_intercept = normal(), prior_aux = cauchy(0, 5),
```

```
prior_covariance = lkj(), prior_PD = FALSE,
algorithm = c("sampling", "meanfield", "fullrank"),
adapt_delta = NULL, max_treedepth = 10L, init = "random",
QR = FALSE, sparse = FALSE, ...)
```

Arguments

formula	A two-sided linear formula object describing both the fixed-effects and random-effects parts of the longitudinal submodel similar in vein to formula specification in the lme4 package (see glmer or the lme4 vignette for details). Note however that the double bar () notation is not allowed when specifying the random-effects parts of the formula, and neither are nested grouping factors (e.g. (1 g1/g2)) or (1 g1:g2), where g1, g2 are grouping factors. For a multivariate GLM this should be a list of such formula objects, with each element of the list providing the formula for one of the GLM submodels.
data	A data frame containing the variables specified in formula. For a multivariate GLM, this can be either a single data frame which contains the data for all GLM submodels, or it can be a list of data frames where each element of the list provides the data for one of the GLM submodels.
family	The family (and possibly also the link function) for the GLM submodel(s). See glmer for details. If fitting a multivariate GLM, then this can optionally be a list of families, in which case each element of the list specifies the family for one of the GLM submodels. In other words, a different family can be specified for each GLM submodel.
weights	Same as in glm , except that when fitting a multivariate GLM and a list of data frames is provided in data then a corresponding list of weights must be provided. If weights are provided for one of the GLM submodels, then they must be provided for all GLM submodels.
prior, prior_intercept, prior_aux	Same as in stan_glmer except that for a multivariate GLM a list of priors can be provided for any of prior, prior_intercept or prior_aux arguments. That is, different priors can optionally be specified for each of the GLM submodels. If a list is not provided, then the same prior distributions are used for each GLM submodel. Note that the "product_normal" prior is not allowed for stan_mvmer.
prior_covariance	Cannot be NULL; see priors for more information about the prior distributions on covariance matrices. Note however that the default prior for covariance matrices in stan_mvmer is slightly different to that in stan_glmer (the details of which are described on the priors page).
prior_PD	A logical scalar (defaulting to FALSE) indicating whether to draw from the prior predictive distribution instead of conditioning on the outcome.
algorithm	A string (possibly abbreviated) indicating the estimation approach to use. Can be "sampling" for MCMC (the default), "optimizing" for optimization, "meanfield" for variational inference with independent normal distributions, or "fullrank" for variational inference with a multivariate normal distribution. See rstanarm-package for more details on the estimation algorithms. NOTE: not all fitting functions support all four algorithms.

adapt_delta	Only relevant if algorithm="sampling". See the adapt_delta help page for details.
max_treedepth	A positive integer specifying the maximum treedepth for the non-U-turn sampler. See the control argument in stan .
init	The method for generating initial values. See stan .
QR	A logical scalar defaulting to FALSE, but if TRUE applies a scaled qr decomposition to the design matrix. The transformation does not change the likelihood of the data but is recommended for computational reasons when there are multiple predictors. See the QR-argument documentation page for details on how rstan-arm does the transformation and important information about how to interpret the prior distributions of the model parameters when using QR=TRUE.
sparse	A logical scalar (defaulting to FALSE) indicating whether to use a sparse representation of the design (X) matrix. If TRUE, the the design matrix is not centered (since that would destroy the sparsity) and likewise it is not possible to specify both QR = TRUE and sparse = TRUE. Depending on how many zeros there are in the design matrix, setting sparse = TRUE may make the code run faster and can consume much less RAM.
...	Further arguments passed to the function in the rstan package (sampling , vb , or optimizing), corresponding to the estimation method named by algorithm. For example, if algorithm is "sampling" it is possible to specify iter, chains, cores, refresh, etc.

Details

The `stan_mvmer` function can be used to fit a multivariate generalized linear model (GLM) with group-specific terms. The model consists of distinct GLM submodels, each which contains group-specific terms; within a grouping factor (for example, patient ID) the grouping-specific terms are assumed to be correlated across the different GLM submodels. It is possible to specify a different outcome type (for example a different family and/or link function) for each of the GLM submodels.

Bayesian estimation of the model is performed via MCMC, in the same way as for [stan_glmr](#). Also, similar to [stan_glmr](#), an unstructured covariance matrix is used for the group-specific terms within a given grouping factor, with priors on the terms of a decomposition of the covariance matrix. See [priors](#) for more information about the priors distributions that are available for the covariance matrices, the regression coefficients and the intercept and auxiliary parameters.

Value

A [stanmvreg](#) object is returned.

See Also

[stan_glmr](#), [stan_jm](#), [stanreg-objects](#), [stanmvreg-methods](#), [print.stanmvreg](#), [summary.stanmvreg](#), [posterior_predict](#), [posterior_interval](#).

Examples

```
#####
# A multivariate GLM with two submodels. For the grouping factor 'id', the
# group-specific intercept from the first submodel (logBili) is assumed to
# be correlated with the group-specific intercept and linear slope in the
# second submodel (albumin)
f1 <- stan_mvmer(
  formula = list(
    logBili ~ year + (1 | id),
    albumin ~ sex + year + (year | id)),
  data = pbcLong,
  # this next line is only to keep the example small in size!
  chains = 1, cores = 1, seed = 12345, iter = 1000)
summary(f1)

#####
# A multivariate GLM with one bernoulli outcome and one
# gaussian outcome. We will artificially create the bernoulli
# outcome by dichotomising log serum bilirubin
pbcLong$ybern <- as.integer(pbcLong$logBili >= mean(pbcLong$logBili))
f2 <- stan_mvmer(
  formula = list(
    ybern ~ year + (1 | id),
    albumin ~ sex + year + (year | id)),
  data = pbcLong,
  family = list(binomial, gaussian),
  chains = 1, cores = 1, seed = 12345, iter = 1000)
```

 stan_nlmer

Bayesian nonlinear models with group-specific terms via Stan

Description

Bayesian inference for NLMMs with group-specific coefficients that have unknown covariance matrices with flexible priors.

Usage

```
stan_nlmer(formula, data = NULL, subset, weights, na.action, offset,
  contrasts = NULL, ..., prior = normal(), prior_aux = exponential(),
  prior_covariance = decov(), prior_PD = FALSE,
  algorithm = c("sampling", "meanfield", "fullrank"),
  adapt_delta = NULL, QR = FALSE, sparse = FALSE)
```

Arguments

formula, data	Same as for <code>nlmer</code> . <i>We strongly advise against omitting the data argument.</i> Unless data is specified (and is a data frame) many post-estimation functions (including <code>update</code> , <code>loo</code> , <code>kfold</code>) are not guaranteed to work properly.
subset, weights, offset	Same as <code>glm</code> .
na.action, contrasts	Same as <code>glm</code> , but rarely specified.
...	Further arguments passed to the function in the rstan package (<code>sampling</code> , <code>vb</code> , or <code>optimizing</code>), corresponding to the estimation method named by <code>algorithm</code> . For example, if <code>algorithm</code> is "sampling" it is possible to specify <code>iter</code> , <code>chains</code> , <code>cores</code> , <code>refresh</code> , etc.
prior	The prior distribution for the regression coefficients. <code>prior</code> should be a call to one of the various functions provided by rstanarm for specifying priors. The subset of these functions that can be used for the prior on the coefficients can be grouped into several "families":

Family	Functions
<i>Student t family</i>	<code>normal</code> , <code>student_t</code> , <code>cauchy</code>
<i>Hierarchical shrinkage family</i>	<code>hs</code> , <code>hs_plus</code>
<i>Laplace family</i>	<code>laplace</code> , <code>lasso</code>
<i>Product normal family</i>	<code>product_normal</code>

See the [priors help page](#) for details on the families and how to specify the arguments for all of the functions in the table above. To omit a prior—i.e., to use a flat (improper) uniform prior—`prior` can be set to `NULL`, although this is rarely a good idea.

Note: Unless `QR=TRUE`, if `prior` is from the Student t family or Laplace family, and if the `autoscale` argument to the function used to specify the prior (e.g. `normal`) is left at its default and recommended value of `TRUE`, then the default or user-specified prior scale(s) may be adjusted internally based on the scales of the predictors. See the [priors help page](#) and the *Prior Distributions* vignette for details on the rescaling and the `prior_summary` function for a summary of the priors used for a particular model.

prior_aux	The prior distribution for the "auxiliary" parameter (if applicable). The "auxiliary" parameter refers to a different parameter depending on the family. For Gaussian models <code>prior_aux</code> controls "sigma", the error standard deviation. For negative binomial models <code>prior_aux</code> controls "reciprocal_dispersion", which is similar to the "size" parameter of <code>rnbinom</code> : smaller values of "reciprocal_dispersion" correspond to greater dispersion. For gamma models <code>prior_aux</code> sets the prior on to the "shape" parameter (see e.g., <code>rgamma</code>), and for inverse-Gaussian models it is the so-called "lambda" parameter (which is essentially the reciprocal of a scale parameter). Binomial and Poisson models do not have auxiliary parameters. <code>prior_aux</code> can be a call to <code>exponential</code> to use an exponential distribution, or
-----------	---

	normal, student_t or cauchy, which results in a half-normal, half-t, or half-Cauchy prior. See priors for details on these functions. To omit a prior —i.e., to use a flat (improper) uniform prior— set prior_aux to NULL.
prior_covariance	Cannot be NULL; see decov for more information about the default arguments.
prior_PD	A logical scalar (defaulting to FALSE) indicating whether to draw from the prior predictive distribution instead of conditioning on the outcome.
algorithm	A string (possibly abbreviated) indicating the estimation approach to use. Can be "sampling" for MCMC (the default), "optimizing" for optimization, "meanfield" for variational inference with independent normal distributions, or "fullrank" for variational inference with a multivariate normal distribution. See rstanarm-package for more details on the estimation algorithms. NOTE: not all fitting functions support all four algorithms.
adapt_delta	Only relevant if algorithm="sampling". See the adapt_delta help page for details.
QR	A logical scalar defaulting to FALSE, but if TRUE applies a scaled qr decomposition to the design matrix. The transformation does not change the likelihood of the data but is recommended for computational reasons when there are multiple predictors. See the QR-argument documentation page for details on how rstanarm does the transformation and important information about how to interpret the prior distributions of the model parameters when using QR=TRUE.
sparse	A logical scalar (defaulting to FALSE) indicating whether to use a sparse representation of the design (X) matrix. If TRUE, the the design matrix is not centered (since that would destroy the sparsity) and likewise it is not possible to specify both QR = TRUE and sparse = TRUE. Depending on how many zeros there are in the design matrix, setting sparse = TRUE may make the code run faster and can consume much less RAM.

Details

The `stan_nlmer` function is similar in syntax to `nlmer` but rather than performing (approximate) maximum marginal likelihood estimation, Bayesian estimation is by default performed via MCMC. The Bayesian model adds independent priors on the "coefficients" — which are really intercepts — in the same way as `stan_nlmer` and priors on the terms of a decomposition of the covariance matrices of the group-specific parameters. See [priors](#) for more information about the priors.

The supported transformation functions are limited to the named "self-starting" functions in the `stats` library: `SSasymp`, `SSasympOff`, `SSasympOrig`, `SSbiexp`, `SSfol`, `SSfpl`, `SSgomPERTZ`, `SSlogis`, `SSmicmen`, and `SSweibull`.

Value

A `stanreg` object is returned for `stan_nlmer`.

See Also

[stanreg-methods](#) and `nlmer`.

The vignette for `stan_glm`, which also discusses `stan_nlmer` models. <http://mc-stan.org/rstanarm/articles/>

Examples

```
data("Orange", package = "datasets")
Orange$circumference <- Orange$circumference / 100
Orange$age <- Orange$age / 100
fit <- stan_nlmer(
  circumference ~ SSlogis(age, Asym, xmid, scal) ~ Asym|Tree,
  data = Orange,
  # for speed only
  chains = 1,
  iter = 1000
)
print(fit)
posterior_interval(fit)
plot(fit, regex_pars = "b\\[")
```

 stan_polr

Bayesian ordinal regression models via Stan

Description

Bayesian inference for ordinal (or binary) regression models under a proportional odds assumption.

Usage

```
stan_polr(formula, data, weights, ..., subset,
  na.action = getOption("na.action", "na.omit"), contrasts = NULL,
  model = TRUE, method = c("logistic", "probit", "loglog", "cloglog",
  "cauchit"), prior = R2(stop("'location' must be specified")),
  prior_counts = dirichlet(1), shape = NULL, rate = NULL,
  prior_PD = FALSE, algorithm = c("sampling", "meanfield", "fullrank"),
  adapt_delta = NULL, do_residuals = NULL)
```

```
stan_polr.fit(x, y, wt = NULL, offset = NULL, method = c("logistic",
  "probit", "loglog", "cloglog", "cauchit"), ...,
  prior = R2(stop("'location' must be specified")),
  prior_counts = dirichlet(1), shape = NULL, rate = NULL,
  prior_PD = FALSE, algorithm = c("sampling", "meanfield", "fullrank"),
  adapt_delta = NULL, do_residuals = algorithm == "sampling")
```

Arguments

formula, data, subset

Same as [polr](#), but *we strongly advise against omitting the data argument*. Unless data is specified (and is a data frame) many post-estimation functions (including update, loo, kfold) are not guaranteed to work properly.

weights, na.action, contrasts, model	Same as polr , but rarely specified.
...	Further arguments passed to the function in the rstan package (sampling , vb , or optimizing), corresponding to the estimation method named by <code>algorithm</code> . For example, if <code>algorithm</code> is "sampling" it is possible to specify <code>iter</code> , <code>chains</code> , <code>cores</code> , <code>refresh</code> , etc.
method	One of 'logistic', 'probit', 'loglog', 'cloglog' or 'cauchit', but can be abbreviated. See polr for more details.
prior	Prior for coefficients. Should be a call to R2 to specify the prior location of the R^2 but can be NULL to indicate a standard uniform prior. See priors .
prior_counts	A call to dirichlet to specify the prior counts of the outcome when the predictors are at their sample means.
shape	Either NULL or a positive scalar that is interpreted as the shape parameter for a GammaDistribution on the exponent applied to the probability of success when there are only two outcome categories. If NULL, which is the default, then the exponent is taken to be fixed at 1.
rate	Either NULL or a positive scalar that is interpreted as the rate parameter for a GammaDistribution on the exponent applied to the probability of success when there are only two outcome categories. If NULL, which is the default, then the exponent is taken to be fixed at 1.
prior_PD	A logical scalar (defaulting to FALSE) indicating whether to draw from the prior predictive distribution instead of conditioning on the outcome.
algorithm	A string (possibly abbreviated) indicating the estimation approach to use. Can be "sampling" for MCMC (the default), "optimizing" for optimization, "meanfield" for variational inference with independent normal distributions, or "fullrank" for variational inference with a multivariate normal distribution. See rstanarm-package for more details on the estimation algorithms. NOTE: not all fitting functions support all four algorithms.
adapt_delta	Only relevant if <code>algorithm="sampling"</code> . See the adapt_delta help page for details.
do_residuals	A logical scalar indicating whether or not to automatically calculate fit residuals after sampling completes. Defaults to TRUE if and only if <code>algorithm="sampling"</code> . Setting <code>do_residuals=FALSE</code> is only useful in the somewhat rare case that <code>stan_polr</code> appears to finish sampling but hangs instead of returning the fitted model object.
x	A design matrix.
y	A response variable, which must be a (preferably ordered) factor.
wt	A numeric vector (possibly NULL) of observation weights.
offset	A numeric vector (possibly NULL) of offsets.

Details

The `stan_polr` function is similar in syntax to [polr](#) but rather than performing maximum likelihood estimation of a proportional odds model, Bayesian estimation is performed (if `algorithm = "sampling"`)

via MCMC. The `stan_polr` function calls the workhorse `stan_polr.fit` function, but it is possible to call the latter directly.

As for `stan_lm`, it is necessary to specify the prior location of R^2 . In this case, the R^2 pertains to the proportion of variance in the latent variable (which is discretized by the cutpoints) attributable to the predictors in the model.

Prior beliefs about the cutpoints are governed by prior beliefs about the outcome when the predictors are at their sample means. Both of these are explained in the help page on `priors` and in the `rstanarm` vignettes.

Unlike `polr`, `stan_polr` also allows the "ordinal" outcome to contain only two levels, in which case the likelihood is the same by default as for `stan_glm` with `family = binomial` but the prior on the coefficients is different. However, `stan_polr` allows the user to specify the shape and rate hyperparameters, in which case the probability of success is defined as the logistic CDF of the linear predictor, raised to the power of `alpha` where `alpha` has a gamma prior with the specified shape and rate. This likelihood is called "scobit" by Nagler (1994) because if `alpha` is not equal to 1, then the relationship between the linear predictor and the probability of success is skewed. If shape or rate is `NULL`, then `alpha` is assumed to be fixed to 1.

Otherwise, it is usually advisable to set shape and rate to the same number so that the expected value of `alpha` is 1 while leaving open the possibility that `alpha` may depart from 1 a little bit. It is often necessary to have a lot of data in order to estimate `alpha` with much precision and always necessary to inspect the Pareto shape parameters calculated by `loo` to see if the results are particularly sensitive to individual observations.

Users should think carefully about how the outcome is coded when using a scobit-type model. When `alpha` is not 1, the asymmetry implies that the probability of success is most sensitive to the predictors when the probability of success is less than 0.63. Reversing the coding of the successes and failures allows the predictors to have the greatest impact when the probability of failure is less than 0.63. Also, the gamma prior on `alpha` is positively skewed, but you can reverse the coding of the successes and failures to circumvent this property.

Value

A `stanreg` object is returned for `stan_polr`.

A `stanfit` object (or a slightly modified `stanfit` object) is returned if `stan_polr.fit` is called directly.

References

Nagler, J., (1994). Scobit: An Alternative Estimator to Logit and Probit. *American Journal of Political Science*. 230 – 255.

See Also

`stanreg-methods` and `polr`.

The vignette for `stan_polr`. <http://mc-stan.org/rstanarm/articles/>

Examples

```
if (!grepl("^sparc", R.version$platform)) {
  fit <- stan_polr(tobgp ~ agegp, data = esoph, method = "probit",
```

```

      prior = R2(0.2, "mean"), init_r = 0.1, seed = 12345,
      algorithm = "fullrank") # for speed only
print(fit)
plot(fit)
}

```

summary.stanreg

*Summary method for stanreg objects***Description**

Summaries of parameter estimates and MCMC convergence diagnostics (Monte Carlo error, effective sample size, Rhat).

Usage

```

## S3 method for class 'stanreg'
summary(object, pars = NULL, regex_pars = NULL,
        probs = NULL, ..., digits = 1)

## S3 method for class 'summary.stanreg'
print(x, digits = max(1, attr(x,
    "print.digits")), ...)

## S3 method for class 'summary.stanreg'
as.data.frame(x, ...)

## S3 method for class 'stanmvreg'
summary(object, pars = NULL, regex_pars = NULL,
        probs = NULL, ..., digits = 3)

## S3 method for class 'summary.stanmvreg'
print(x, digits = max(1, attr(x,
    "print.digits")), ...)

```

Arguments

object	A fitted model object returned by one of the rstanarm modeling functions. See stanreg-objects .
pars	An optional character vector specifying a subset of parameters to display. Parameters can be specified by name or several shortcuts can be used. Using <code>pars="beta"</code> will restrict the displayed parameters to only the regression coefficients (without the intercept). <code>"alpha"</code> can also be used as a shortcut for <code>"(Intercept)"</code> . If the model has varying intercepts and/or slopes they can be selected using <code>pars = "varying"</code> .

In addition, for stanmvreg objects there are some additional shortcuts available. Using `pars = "long"` will display the parameter estimates for the longitudinal submodels only (excluding group-specific parameters, but including auxiliary parameters). Using `pars = "event"` will display the parameter estimates for the event submodel only, including any association parameters. Using `pars = "assoc"` will display only the association parameters. Using `pars = "fixef"` will display all fixed effects, but not the random effects or the auxiliary parameters. `pars` and `regex_pars` are set to `NULL` then all fixed effect regression coefficients are selected, as well as any auxiliary parameters and the log posterior.

If `pars` is `NULL` all parameters are selected for a `stanreg` object, while for a `stanmvreg` object all fixed effect regression coefficients are selected as well as any auxiliary parameters and the log posterior. See **Examples**.

<code>regex_pars</code>	An optional character vector of regular expressions to use for parameter selection. <code>regex_pars</code> can be used in place of <code>pars</code> or in addition to <code>pars</code> . Currently, all functions that accept a <code>regex_pars</code> argument ignore it for models fit using optimization.
<code>probs</code>	For models fit using MCMC or one of the variational algorithms, an optional numeric vector of probabilities passed to quantile .
<code>...</code>	Currently ignored.
<code>digits</code>	Number of digits to use for formatting numbers when printing. When calling <code>summary</code> , the value of <code>digits</code> is stored as the <code>"print.digits"</code> attribute of the returned object.
<code>x</code>	An object of class <code>"summary.stanreg"</code> .

Value

The `summary` method returns an object of class `"summary.stanreg"` (or `"summary.stanmvreg"`, inheriting `"summary.stanreg"`), which is a matrix of summary statistics and diagnostics, with attributes storing information for use by the `print` method. The `print` method for `summary.stanreg` or `summary.stanmvreg` objects is called for its side effect and just returns its input. The `as.data.frame` method for `summary.stanreg` objects converts the matrix to a `data.frame`, preserving row and column names but dropping the `print`-related attributes.

See Also

[prior_summary](#) to extract or print a summary of the priors used for a particular model.

Examples

```
if (!exists("example_model")) example(example_model)
summary(example_model, probs = c(0.1, 0.9))

# These produce the same output for this example,
# but the second method can be used for any model
summary(example_model, pars = c("Intercept", "size",
                               paste0("period", 2:4)))
summary(example_model, pars = c("alpha", "beta"))
```

```
# Only show parameters varying by group
summary(example_model, pars = "varying")
as.data.frame(summary(example_model, pars = "varying"))
```

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