Package ‘baggr’

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Type Package

Title Bayesian Aggregate Treatment Effects

Version 0.7.11

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Description Running and comparing meta-analyses of data with hierarchical Bayesian models in Stan, including convenience functions for formatting data, plotting and pooling measures specific to meta-analysis. This implements many models from Meager (2019) <doi:10.1257/app.20170299>.

License GPL (>= 3)

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Contents

`add_color_to_plot` *Add colors to baggr plots*

Description

Add colors to baggr plots

Usage

```
add_color_to_plot(p, what)
```

Arguments

`p`	A ggplot object to add colors to
`what`	A named vector, e.g. `c(Hypermean = "red", "Group A" = "green")`.

`baggr` *Bayesian aggregate treatment effects model*

Description

Bayesian inference on parameters of an average treatment effects model that's appropriate to the supplied individual- or group-level data, using Hamiltonian Monte Carlo in Stan. (For overall package help file see baggr-package)

Usage

```
baggr(
  data,
  model = NULL,
  pooling = c("partial", "none", "full"),
  effect_label = NULL,
  covariates = c(),
  prior_hypermean = NULL,
  prior_hypersd = NULL,
  prior_hypercor = NULL,
  prior_beta = NULL,
```

```
  prior_cluster = NULL,
  prior_control = NULL,
  prior_control_sd = NULL,
  prior_sigma = NULL,
  prior = NULL,
  ppd = FALSE,
  pooling_control = c("none", "partial", "remove"),
  test_data = NULL,
  quantiles = seq(0.05, 0.95, 0.1),
  outcome = "outcome",
  group = "group",
  treatment = "treatment",
  cluster = NULL,
  silent = FALSE,
  warn = TRUE,
  ...
)
```

Arguments

`data`	data frame with summary or individual level data to meta-analyse; see Details section for how to format your data
`model`	if `NULL`, detected automatically from input data otherwise choose from `"rubin"`, `"mutau"`, `"rubin_full"`, `"quantiles"` (see Details).
`pooling`	Type of pooling; choose from `"none"`, `"partial"` (default) and `"full"`. If you are not familiar with the terms, consult the vignette; "partial" can be understood as random effects and "full" as fixed effects
`effect_label`	How to label the effect(s). These labels are used in various print and plot outputs. Will default to `"mean"` in most models, `"log OR"` in logistic model etc. If you plan on comparing models (see baggr_compare), use the same labels.
`covariates`	Character vector with column names in `data`. The corresponding columns are used as covariates (fixed effects) in the meta-regression model (in case of aggregate data). In the case of individual level data the model does not differentiate between group-level variables (same values of the covariate for all rows related to a given group) and individual-level covariates.
`prior_hypermean`	prior distribution for hypermean; you can use "plain text" notation like `prior_hypermean=normal(0,100` or `uniform(-10, 10)`. See *Details:Priors* section below for more possible specifications. If unspecified, the priors will be derived automatically based on data (and printed out in the console).
`prior_hypersd`	prior for hyper-standard deviation, used by Rubin and `"mutau"` models; same rules apply as for `_hypermean`;
`prior_hypercor`	prior for hypercorrelation matrix, used by the `"mutau"` model
`prior_beta`	prior for regression coefficients if `covariates` are specified; will default to experimental normal(0, 10^2) distribution
`prior_cluster`	priors for SDs of cluster random effects in each study (i.e. assuming normal(0, sigma_k^2), with different sigma in each group)

`prior_control`	prior for the mean in the control arm (baseline), currently used in `"logit"` model only; if `pooling_control = "partial"`, the prior is hyperprior for all baselines, if `"none"`, then it is an independent prior for all baselines
`prior_control_sd`	prior for the SD in the control arm (baseline), currently used in `"logit"` model only; this can only be used if `pooling_control = "partial"`
`prior_sigma`	prior for error terms in linear regression models (`"rubin_full"` or `"mutau_full"`)
`prior`	alternative way to specify all priors as a named list with `hypermean`, `hypersd`, `hypercor`, `beta`, analogous to `prior_` arguments above, e.g. `prior = list(hypermean = normal(0,10), beta = uniform(-50, 50))`
`ppd`	logical; use prior predictive distribution? (*p.p.d.*) If `ppd=TRUE`, Stan model will sample from the prior distribution(s) and ignore `data` in inference. However, `data` argument might still be used to infer the correct model (if `model=NULL`) and to set the default priors, therefore you must specify it.
`pooling_control`	Pooling for group-specific control mean terms in models using individual-level data. Typically we use either `"none"` or `"partial"`, but if you want to remove the group-specific intercept altogether, set this to `"remove"`.
`test_data`	data for cross-validation; NULL for no validation, otherwise a data frame with the same columns as `data` argument. See "Cross-validation" section below.
`quantiles`	if `model = "quantiles"`, a vector indicating which quantiles of data to use (with values between 0 and 1)
`outcome`	column name in `data` (used in individual-level only) with outcome variable values
`group`	column name in `data` with grouping factor; it's necessary for individual-level data, for summarised data it will be used as labels for groups when displaying results
`treatment`	column name in (individual-level) `data` with treatment factor;
`cluster`	optional; column name in (individual-level) `data`; if defined, random cluster effects will be fitted in each study
`silent`	Whether to silence messages about prior settings and about other automatic behaviour.
`warn`	print an additional warning if Rhat exceeds 1.05
`...`	extra options passed to Stan function, e.g. `control = list(adapt_delta = 0.99)`, number of iterations etc.

Details

Below we briefly discuss 1/ data preparation, 2/ choice of model, 3/ choice of priors. All three are discussed in more depth in the package vignette, `vignette("baggr")`.

Data. For aggregate data models you need a data frame with columns `tau` and `se` (Rubin model) or `tau`, `mu`, `se.tau`, `se.mu` ("mu & tau" model). An additional column can be used to provide labels for each group (by default column `group` is used if available, but this can be customised – see the example below). For individual level data three columns are needed: outcome, treatment, group. These are identified by using the `outcome`, `treatment` and `group` arguments.

Many data preparation steps can be done through a helper function prepare_ma. It can convert individual to summary-level data, calculate odds/risk ratios (with/without corrections) in binary data, standardise variables and more. Using it will automatically format data inputs to work with `baggr()`.

Models. Available models are:

- for the **continuous variable** means: `"rubin"` model for average treatment effect (using summary data), `"mutau"` version which takes into account means of control groups (also using summary data), `"rubin_full"`, which is the same model as `"rubin"` but works with individual-level data
- for **binary data**: `"logit"` model can be used on individual-level data; you can also analyse continuous statistics such as log odds ratios and logs risk ratios using the models listed above; see `vignette("baggr_binary")` for tutorial with examples

If no model is specified, the function tries to infer the appropriate model automatically. Additionally, the user must specify type of pooling. The default is always partial pooling.

Covariates. Both aggregate and individual-level data can include extra columns, given by `covariates` argument (specified as a character vector of column names) to be used in regression models. We also refer to impact of these covariates as *fixed effects*.

Two types of covariates may be present in your data:

- In `"rubin"` and `"mutau"` models, covariates that **change according to group unit**. In that case, the model accounting for the group covariates is a meta-regression model. It can be modelled on summary-level data.
- In `"logit"` and `"rubin_full"` models, covariates that **change according to individual unit**. Then, such a model is often referred to as a mixed model. It has to be fitted to individual-level data. Note that meta-regression is a special case of a mixed model for individual-level data.

Priors. It is optional to specify priors yourself, as the package will try propose an appropriate prior for the input data if you do not pass a `prior` argument. To set the priors yourself, use `prior_` arguments. For specifying many priors at once (or re-using between models), a single `prior = list(...)` argument can be used instead. Meaning of the prior parameters may slightly change from model to model. Details and examples are given in `vignette("baggr")`. Setting `ppd=TRUE` can be used to obtain prior predictive distributions, which is useful for understanding the prior assumptions, especially useful in conjunction with effect_plot. You can also baggr_compare different priors by setting `baggr_compare(..., compare="prior")`.

Cross-validation. When `test_data` are specified, an extra parameter, the log predictive density, will be returned by the model. (The fitted model itself is the same regardless of whether there are `test_data`.) To understand this parameter, see documentation of loocv, a function that can be used to assess out of sample prediction of the model using all available data. If using individual-level data model, `test_data` should only include treatment arms of the groups of interest. (This is because in cross-validation we are not typically interested in the model's ability to fit heterogeneity in control arms, but only heterogeneity in treatment arms.) For using aggregate level data, there is no such restriction.

Outputs. By default, some outputs are printed. There is also a plot method for *baggr* objects which you can access via baggr_plot (or simply `plot()`). Other standard functions for working with `baggr` object are

- treatment_effect for distribution of hyperparameters
- group_effects for distributions of group-specific parameters (alias: study_effects, we use the two interchangeably)
- fixed_effects for coefficients in (meta-)regression
- effect_draw and effect_plot for posterior predictive distributions
- baggr_compare for comparing multiple `baggr` models
- loocv for cross-validation

Value

`baggr` class structure: a list including Stan model fit alongside input data, pooling metrics, various model properties. If test data is used, mean value of -2*lpd is reported as `mean_lpd`

Examples

```
df_pooled <- data.frame("tau" = c(1, -1, .5, -.5, .7, -.7, 1.3, -1.3),
                        "se" = rep(1, 8),
                        "state" = datasets::state.name[1:8])
baggr(df_pooled) #baggr automatically detects the input data
# same model, but with correct labels,
# different pooling & passing some options to Stan
baggr(df_pooled, group = "state", pooling = "full", iter = 500)
# model with non-default (and very informative) priors

baggr(df_pooled, prior_hypersd = normal(0, 2))


# "mu & tau" model, using a built-in dataset
# prepare_ma() can summarise individual-level data
ms <- microcredit_simplified
microcredit_summary_data <- prepare_ma(ms, outcome = "consumption")
baggr(microcredit_summary_data, model = "mutau",
      iter = 500, #this is just for illustration -- don't set it this low normally!
      pooling = "partial", prior_hypercor = lkj(1),
      prior_hypersd = normal(0,10),
      prior_hypermean = multinormal(c(0,0),matrix(c(10,3,3,10),2,2)))
```

`baggr_compare` *(Run and) compare multiple baggr models*

Description

Compare multiple baggr models by either providing multiple already existing models as (named) arguments or passing parameters necessary to run a baggr model.

Usage

```
baggr_compare(
  ...,
  what = "pooling",
  compare = c("groups", "hyperpars", "effects"),
  transform = NULL,
  prob = 0.95,
  plot = FALSE
)
```

Arguments

`...`	Either some (at least 1) objects of class `baggr` (you should name your objects, see the example below) or the same arguments you'd pass to baggr. In the latter case you must specify `what` to compare.
`what`	One of `"pooling"` (comparison between no, partial and full pooling) or `"prior"` (comparison between prior and posterior predictive). If pre-existing baggr models are passed to `...`, this argument is ignored.
`compare`	When plotting, choose between comparison of `"groups"` (default), `"hyperpars"` (to omit group-specific estimates) or (predicted) `"effects"`. The `"groups"` option is not available when `what = "prior"`.
`transform`	a function (e.g. exp(), log()) to apply to the the sample of group (and hyper, if `hyper=TRUE`) effects before plotting; when working with effects that are on log scale, exponent transform is used automatically, you can plot on log scale by setting transform = identity
`prob`	Width of uncertainty interval (defaults to 95%)
`plot`	logical; calls plot.baggr_compare when running `baggr_compare`

Details

If you pass parameters to the function you must specify what kind of comparison you want, either `"pooling"`, which will run fully/partially/un-pooled models and then compare them, or `"prior"` which will generate estimates without the data and compare them to the model with the full data. For more details see baggr, specifically the ppd argument.

Value

an object of class `baggr_compare`

Author(s)

Witold Wiecek, Brice Green

See Also

plot.baggr_compare and print.baggr_compare for working with results of this function

Examples

```
# Most basic comparison between no, partial and full pooling
# (This will run the models)
# run model with just prior and then full data for comparison
# with the same arguments that are passed to baggr
prior_comparison <-
  baggr_compare(schools,
                model = 'rubin',
                #this is just for illustration -- don't set it this low normally!
                iter = 500,
                prior_hypermean = normal(0, 3),
                prior_hypersd = normal(0,2),
                prior_hypercor = lkj(2),
                what = "prior")
# print the aggregated treatment effects
prior_comparison
# plot the comparison of the two distributions
plot(prior_comparison)
# Now compare different types of pooling for the same model
pooling_comparison <-
  baggr_compare(schools,
                model = 'rubin',
                #this is just for illustration -- don't set it this low normally!
                iter = 500,
                prior_hypermean = normal(0, 3),
                prior_hypersd = normal(0,2),
                prior_hypercor = lkj(2),
                what = "pooling",
                # You can automatically plot:
                plot = TRUE)
# Compare existing models (you don't have to, but best to name them):
bg1 <- baggr(schools, pooling = "partial")
bg2 <- baggr(schools, pooling = "full")
baggr_compare("Partial pooling model" = bg1, "Full pooling" = bg2)

#' ...or simply draw from prior predictive dist (note ppd=T)
bg1 <- baggr(schools, ppd=TRUE)
bg2 <- baggr(schools, prior_hypermean = normal(0, 5), ppd=TRUE)
baggr_compare("Prior A, p.p.d."=bg1,
              "Prior B p.p.d."=bg2,
              compare = "effects")

# Compare how posterior predictive effect varies with e.g. choice of prior
bg1 <- baggr(schools, prior_hypersd = uniform(0, 20))
bg2 <- baggr(schools, prior_hypersd = normal(0, 5))
baggr_compare("Uniform prior on SD"=bg1,
                   "Normal prior on SD"=bg2,
                   compare = "effects", plot = TRUE)

# Models don't have to be identical. Compare different subsets of input data:
bg1_small <- baggr(schools[1:6,], pooling = "partial")
baggr_compare("8 schools model" = bg1, "First 6 schools" = bg1_small,
```

```
          plot = TRUE)
```

`baggr_plot` *Plotting method in baggr package*

Description

Extracts study effects from the `baggr` model and plots them, possibly next to the hypereffect estimate.

Usage

```
baggr_plot(
  bg,
  hyper = FALSE,
  style = c("intervals", "areas", "forest_plot"),
  transform = NULL,
  prob = 0.5,
  prob_outer = 0.95,
  vline = TRUE,
  order = TRUE,
  values_outer = TRUE,
  values_size = 4,
  values_digits = 1,
  ...
)
```

Arguments

`bg`	object of class `baggr`
`hyper`	logical; show hypereffect as the last row of the plot? alternatively you can pass colour for the hypermean row, e.g. `hyper = "red"`
`style`	`"forest_plot"` imitates the visual style of forest plots and also prints means and intervals next to each row; `"intervals"` (default) or `"areas"` use package `bayesplot` styles
`transform`	a function (e.g. `exp()`, `log()`) to apply to the values of group (and hyper, if `hyper=TRUE`) effects before plotting; when working with effects that are on log scale, exponent transform is used automatically, you can plot on log scale by setting `transform = identity`
`prob`	Probability mass for the inner interval in visualisation
`prob_outer`	Probability mass for the outer interval in visualisation
`vline`	logical; show vertical line through 0 in the plot?
`order`	logical; sort groups by magnitude of treatment effect?

`values_outer`	logical; use the interval corresponding to `prob_outer` when `style = "forest_plot"`? if not, the "inner" interval (`prob`) is used
`values_size`	size of the text values in the plot when `style = "forest_plot"`
`values_digits`	number of significant digits to use when `style = "forest_plot"`
`...`	extra arguments to pass to the `bayesplot` functions

Value

ggplot2 object

Author(s)

Witold Wiecek; the visual style is based on *bayesplot* package

See Also

bayesplot::MCMC-intervals for more information about *bayesplot* functionality; forest_plot for a typical meta-analysis alternative (which you can imitate using `style = "forest_plot"`); effect_plot for plotting treatment effects for a new group

Examples

```
fit <- baggr(schools, pooling = "none")
plot(fit, hyper = "red")
plot(fit, style = "areas", order = FALSE)
plot(fit, style = "forest_plot", order = FALSE)
```

`baggr_theme_set` *Set, get, and replace themes for baggr plots*

Description

These functions get, set, and modify the ggplot2 themes of the baggr plots. `baggr_theme_get()` returns a ggplot2 theme function for adding themes to a plot. `baggr_theme_set()` assigns a new theme for all plots of baggr objects. `baggr_theme_update()` edits a specific theme element for the current theme while holding the theme's other aspects constant. `baggr_theme_replace()` is used for wholesale replacing aspects of a plot's theme (see `ggplot2::theme_get()`).

Usage

```
baggr_theme_set(new = bayesplot::theme_default())

baggr_theme_get()

baggr_theme_update(...)

baggr_theme_replace(...)
```

Arguments

`new`	New theme to use for all baggr plots
`...`	A named list of theme settings

Details

Under the hood, many of the visualizations rely on the bayesplot package, and thus these leverage the `bayesplot::bayesplot_theme_get()` functions. By default, these match the bayesplot's package theme to make it easier to form cohesive graphs across this package and others. The trickiest of these to use is `baggr_theme_replace`; 9 times out of 10 you want baggr_theme_update.

Value

The get method returns the current theme, but all of the others invisibly return the old theme.

See Also

bayesplot::bayesplot_theme_get

Examples

```
# make plot look like default ggplots

library(ggplot2)

fit <- baggr(schools)
baggr_theme_set(theme_grey())
baggr_plot(fit)

# use baggr_theme_get to return theme elements for current theme
qplot(mtcars$mpg) + baggr_theme_get()

# update specific aspect of theme you are interested in
baggr_theme_update(text = element_text(family = "mono"))

# undo that silliness
baggr_theme_update(text = element_text(family = "serif"))

# update and replace are similar, but replace overwrites the
# whole element, update just edits the aspect of the element
# that you give it
# this will error:
# baggr_theme_replace(text = element_text(family = "Times"))
# baggr_plot(fit)
# because it deleted everything else to do with text elements
```

`binary_to_individual` *Generate individual-level binary outcome data from an aggregate statistics*

Description

This is a helper function that is typically used automatically by some of *baggr* functions, such as when running `model="logit"` in baggr, when summary-level data are supplied.

Usage

```
binary_to_individual(
  data,
  group = "group",
  covariates = c(),
  rename_group = TRUE
)
```

Arguments

`data`	A data frame with columns `a`, `c` and `b`/`n1`, `d`/`n2`. (You can also use `ai`, `ci`, `n1i`, `n2i` instead.)
`group`	Column name storing group
`covariates`	Column names in `data` that contain group-level variables to retain when expanding into individual-level `data.frame`
`rename_group`	If `TRUE` (default), this will rename the grouping variable to `"group"`, making it easier to work with baggr See `vignette("baggr_binary")` for an example of use and notation details.

Value

A data frame with columns `group`, `outcome` and `treatment`.

See Also

prepare_ma uses this function

Examples

```
df_yusuf <- read.table(text="
  trial         a n1i  c n2i
  Balcon       14  56 15  58
  Clausen      18  66 19  64
  Multicentre 15 100 12  95
  Barber       10  52 12  47
  Norris       21 226 24 228
  Kahler        3  38  6  31
```

```
  Ledwich      2  20  3  20
  ", header=TRUE)
bti <- binary_to_individual(df_yusuf, group = "trial")
head(bti)
# to go back to summary-level data
prepare_ma(bti, effect = "logOR")
# the last operation is equivalent to simply doing
prepare_ma(df_yusuf, group="trial", effect="logOR")
```

`bubble` *Bubble plots for meta-regression models*

Description

Bubble plots for meta-regression models

Usage

```
bubble(bg, covariate, fit = TRUE, label = TRUE)
```

Arguments

`bg`	a `baggr()` model using summary-level data, with covariates
`covariate`	one of the covariates present in the model
`fit`	logical: show mean model prediction? (slope is mean estimate of `fixed_effects()`, intercept is `hypermean()`); if you have more than two groups and the covariate is a factor, this will be ignored
`label`	logical: label study/group names?

Value

A simple bubble plot in `ggplot` style. Dot sizes are proportional to inverse of variance of each study (more precise studies are larger).

See Also

`labbe()` for an exploratory plot of binary data in similar style

`chicks` *Chickens: impact of electromagnetic field on calcium ion efflux in chicken brains*

Description

An experiment conducted by Blackman et al. (1988) and documented in the following GitHub repository by Vakar and Gelman. The dataset consists of a large number of experiments (`tau`, `se.tau`) repeated at varying wave frequencies. Sham experiments (`mu`, `se.mu`) are also included, allowing us to compare performance of models with and without control measurements.

Usage

```
chicks
```

Format

An object of class `data.frame` with 38 rows and 7 columns.

References

Blackman, C. F., S. G. Benane, D. J. Elliott, D. E. House, and M. M. Pollock. “Influence of Electromagnetic Fields on the Efflux of Calcium Ions from Brain Tissue in Vitro: A Three-Model Analysis Consistent with the Frequency Response up to 510 Hz.” Bioelectromagnetics 9, no. 3 (1988): 215–27.

`convert_inputs` *Convert inputs for baggr models*

Description

Converts data to a list of inputs suitable for Stan models, checks integrity of data and suggests the appropriate default model if needed. Typically all of this is done automatically by baggr, so **this function is included only for debugging** or running (custom) models "by hand".

Usage

```
convert_inputs(
  data,
  model,
  quantiles,
  effect = NULL,
  group = "group",
  outcome = "outcome",
  treatment = "treatment",
  cluster = NULL,
```

```
  covariates = c(),
  test_data = NULL,
  silent = FALSE
)
```

Arguments

`data`	‘data.frame“ with desired modelling input
`model`	valid model name used by baggr; see baggr for allowed models if `model = NULL`, this function will try to find appropriate model automatically
`quantiles`	vector of quantiles to use (only applicable if `model = "quantiles"`)
`effect`	Only matters for binary data, use `logOR`, `logRR`, or `RD`. Otherwise ignore. See prepare_ma for details.
`group`	name of the column with grouping variable
`outcome`	name of column with outcome variable (designated as string)
`treatment`	name of column with treatment variable
`cluster`	name of the column with clustering variable for analysing c-RCTs
`covariates`	Character vector with column names in `data`. The corresponding columns are used as covariates (fixed effects) in the meta-regression model.
`test_data`	same format as `data` argument, gets left aside for testing purposes (see baggr)
`silent`	Whether to print messages when evaluated

Details

Typically this function is only called within baggr and you do not need to use it yourself. It can be useful to understand inputs or to run models which you modified yourself.

Value

R structure that's appropriate for use by baggr Stan models; `group_label`, `model`, `effect` and `n_groups` are included as attributes and are necessary for baggr to work correctly

Author(s)

Witold Wiecek

Examples

```
# simple meta-analysis example,
# this is the formatted input for Stan models in baggr():
convert_inputs(schools, "rubin")
```

`data_spike` *Spike & slab example dataset*

Description

Spike & slab example dataset

Usage

```
data_spike
```

Format

An object of class `data.frame` with 1500 rows and 4 columns.

`effect_draw` *Make predictive draws from baggr model*

Description

The function `effect_draw` and its alias, `posterior_predict`, take the sample of hyperparameters from a baggr model (typically hypermean and hyper-SD, which you can see using treatment_effect) and draws values of new realisations of treatment effect, i.e. an additional draw from the "population of studies". This can be used for both prior and posterior draws, depending on baggr model. By default this is done for a single new effect, but for meta-regression models you can specify values of covariates with the `newdata` argument, same as in predict.

Usage

```
effect_draw(
  object,
  draws = NULL,
  newdata = NULL,
  transform = NULL,
  summary = FALSE,
  message = TRUE,
  interval = 0.95
)
```

Arguments

`object`	A `baggr` class object.
`draws`	How many values to draw? The default is as long as the number of samples in the `baggr` object (see *Details*).

`newdata`	an optional data frame containing new values of covariates that were used when fitting the `baggr` model
`transform`	a transformation (an R function) to apply to the result of a draw.
`summary`	logical; if TRUE returns summary statistics rather than samples from the distribution;
`message`	logical; use to disable messages prompted by using this function with no pooling models
`interval`	uncertainty interval width (numeric between 0 and 1), if `summary=TRUE`

Details

The predictive distribution can be used to "combine" heterogeneity between treatment effects and uncertainty in the mean treatment effect. This is useful both in understanding impact of heterogeneity (see Riley et al, 2011, for a simple introduction) and for study design e.g. as priors in analysis of future data (since the draws can be seen as an expected treatment effect in a hypothetical study).

The default number of samples is the same as what is returned by Stan model implemented in baggr, (depending on such options as `iter`, `chains`, `thin`). If `n` is larger than what is available in Stan model, we draw values with replacement. This is not recommended and warning is printed in these cases.

Under default settings in baggr, a *posterior* predictive distribution is obtained. But `effect_draw` can also be used for *prior* predictive distributions when setting `ppd=T` in baggr. The two outputs work exactly the same way.

If the `baggr` model used by the function is a meta-regression (i.e. a `baggr` model with `covariates`), by specifying the predicted values can be adjusted for known levels of fixed covariates by passing `newdata` (same as in predict). If no adjustment is made, the returned value should be interpreted as the effect when all covariates are 0.

Value

A vector (with `draws` values) for models with one treatment effect parameter, a matrix (`draws` rows and same number of columns as number of parameters) otherwise. If `newdata` are specified, an array is returned instead, where the first dimension corresponds to rows of `newdata`.

References

Riley, Richard D., Julian P. T. Higgins, and Jonathan J. Deeks. "Interpretation of Random Effects Meta-Analyses". *BMJ 342 (10 February 2011).*.

See Also

treatment_effect returns samples from hypermean(s) and hyper-SD(s) which are used by this function

`effect_plot` *Plot predictive draws from baggr model*

Description

This function plots values from effect_draw, the predictive distribution (under default settings, *posterior* predictive), for one or more `baggr` objects.

Usage

```
effect_plot(..., transform = NULL)
```

Arguments

`...`	Object(s) of class baggr. If there is more than one, a comparison will be plotted and names of objects will be used as a plot legend (see examples).
`transform`	a transformation to apply to the result, should be an R function; (this is commonly used when calling group_effects from other plotting or printing functions)

Details

Under default settings in baggr posterior predictive is obtained. But `effect_plot` can also be used for *prior* predictive distributions when setting `ppd=T` in baggr. The two outputs work exactly the same, but labels will change to indicate this difference.

Value

A `ggplot` object.

See Also

effect_draw documents the process of drawing values; baggr_compare can be used as a shortcut for `effect_plot` with argument `compare = "effects"`

Examples

```
# A single effects plot
bg1 <- baggr(schools, prior_hypersd = uniform(0, 20))
effect_plot(bg1)

# Compare how posterior depends on the prior choice
bg2 <- baggr(schools, prior_hypersd = normal(0, 5))
effect_plot("Uniform prior on SD"=bg1,
            "Normal prior on SD"=bg2)

# Compare the priors themselves (ppd=T)
```

```
bg1_ppd <- baggr(schools, prior_hypersd = uniform(0, 20), ppd=TRUE)
bg2_ppd <- baggr(schools, prior_hypersd = normal(0, 5), ppd=TRUE)
effect_plot("Uniform prior on SD"=bg1_ppd,
            "Normal prior on SD"=bg2_ppd)
```

`fixed_effects` *Effects of covariates on outcome in baggr models*

Description

Effects of covariates on outcome in baggr models

Usage

```
fixed_effects(bg, summary = FALSE, transform = NULL, interval = 0.95)
```

Arguments

`bg`	a baggr model
`summary`	logical; if `TRUE` returns summary statistic instead of all MCMC samples
`transform`	a transformation (R function) to apply to the result; (this is commonly used when calling from other plotting or printing functions)
`interval`	uncertainty interval width (numeric between 0 and 1), if `summary=TRUE`

Value

A matrix: columns are covariate coefficients and rows are draws from the posterior distribution. Number of rows depends on iterations in the MCMC (i.e. `x` in baggr(..., iter = x‘)

See Also

treatment_effect for overall treatment effect across groups, group_effects for effects within each group, effect_draw and effect_plot for predicted treatment effect in new group (which you can condition on fixed effects using new data argument)

`forest_plot` *Draw a forest plot for a baggr model*

Description

The forest plot functionality in *baggr* is a simple interface for calling forestplot By default the forest plot displays raw (unpooled) estimates for groups and the treatment effect estimate underneath. This behaviour can be modified to display pooled group estimates.

Usage

```
forest_plot(
  bg,
  show = c("inputs", "posterior", "both", "covariates"),
  print = show,
  prob = 0.95,
  digits = 3,
  ...
)
```

Arguments

`bg`	a baggr class object
`show`	if `"inputs"`, then plotted points and lines correspond to raw inputs for each group; if `"posterior"` – to posterior distribution; you can also plot `"both"` inputs and posteriors; if `"covariates"`, then fixed effect coefficients are plotted
`print`	which values to print next to the plot: values of `"inputs"` or `"posterior"` means? (if `show="covariates"`, it must be `"posterior"`)
`prob`	width of the intervals (lines) for the plot
`digits`	number of digits to display when printing out mean and SD in the plot
`...`	other arguments passed to forestplot

See Also

forestplot function and its vignette for examples; effect_plot and baggr_plot for non-forest plots of baggr results

Examples

```
bg <- baggr(schools, iter = 500)
forest_plot(bg)
forest_plot(bg, show = "posterior", print = "inputs", digits = 2)
```

`get_order` *Separate out ordering so we can test directly*

Description

Separate out ordering so we can test directly

Usage

```
get_order(df_groups, hyper)
```

Arguments

`df_groups`	data.frame of group effects used in plot.baggr_compare
`hyper`	show parameter estimate? same as in plot.baggr_compare

Details

Given a set of effects measured by models, identifies the model which has the biggest range of estimates and ranks groups by those estimates, returning the order

---

`group_effects` *Extract baggr study/group effects*

Description

Given a baggr object, returns the raw MCMC draws of the posterior for each group's effect or a summary of these draws. (We use "group" and "study" interchangeably.) If there are no covariates in the model, this effect is a single random variable. If there are covariates, the group effect is a sum of effect of covariates (fixed effects) and the study-specific random variable (random effects). This is an internal function currently used as a helper for plotting and printing of results.

Usage

```
group_effects(
  bg,
  summary = FALSE,
  transform = NULL,
  interval = 0.95,
  random_only = FALSE,
  rename_int = FALSE
)

study_effects(
  bg,
```

```
  summary = FALSE,
  transform = NULL,
  interval = 0.95,
  random_only = FALSE,
  rename_int = FALSE
)
```

Arguments

`bg`	baggr object
`summary`	logical; if `TRUE` returns summary statistics as explained below.
`transform`	a transformation to apply to the result, should be an R function; (this is commonly used when calling `group_effects` from other plotting or printing functions)
`interval`	uncertainty interval width (numeric between 0 and 1), if summarising
`random_only`	logical; for meta-regression models, should fixed_effects be included in the returned group effect?
`rename_int`	logical; if `TRUE` then rather than returning `median`, `lci` and `uci` columns they are renamed to e.g. `50%`, `2.5%`, `97.5%`; this only works if `summary=TRUE`

Details

If `summary = TRUE`, the returned object contains, for each study or group, the following 5 values: the posterior medians, the lower and upper bounds of the uncertainty intervals using the central posterior credible interval of width specified in the argument `interval`, the posterior mean, and the posterior standard deviation.

Value

Either an array with MCMC samples (if `summary = FALSE`) or a summary of these samples (if `summary = TRUE`). For arrays the three dimensions are: N samples, N groups and N effects (equal to 1 for the basic models).

See Also

fixed_effects for effects of covariates on outcome. To extract random effects when covariates are present, you can use either random_effects or, equivalently, `group_effects(random_only=TRUE)`.

Examples

```
fit1 <- baggr(schools)
group_effects(fit1, summary = TRUE, interval = 0.5)
```

`is.baggr_cv` *Check if something is a baggr_cv object*

Description

Check if something is a baggr_cv object

Usage

```
is.baggr_cv(x)
```

Arguments

`x`	object to check

`labbe` *L'Abbe plot for binary data*

Description

This plot shows relationship between proportions of events in control and treatment groups in binary data.

Usage

```
labbe(
  data,
  group = "group",
  plot_model = FALSE,
  labels = TRUE,
  shade_se = c("rr", "or", "none")
)
```

Arguments

`data`	a data frame with binary data (must have columns `a`, `c`, `b/n1`, `d/n2`)
`group`	a character string specifying group names (e.g. study names), used for labels;
`plot_model`	if `TRUE`, then odds ratios and risk ratios baggr models are estimated (using default settings) and their mean estimates of effects are plotted as lines
`labels`	if `TRUE`, names from the `group` column are displayed
`shade_se`	if `"none"`, nothing is plotted, if `"or"` or `"rr"`, a shaded area corresponding to inverse of effect's (OR or RR) SE is added to each data point; the default is `"rr"`

Value

A `ggplot` object

See Also

`vignette("baggr_binary")` for an illustrative example

`loocv` *Leave one group out cross-validation for* `baggr` *models*

Description

Performs exact leave-one-group-out cross-validation on a baggr model.

Usage

```
loocv(data, return_models = FALSE, ...)
```

Arguments

`data`	Input data frame - same as for baggr function.
`return_models`	logical; if FALSE, summary statistics will be returned and the models discarded; if TRUE, a list of models will be returned alongside summaries
`...`	Additional arguments passed to baggr.

Details

The values returned by `loocv()` can be used to understand how excluding any one group affects the overall result, as well as how well the model predicts the omitted group. LOO-CV approaches are a good general practice for comparing Bayesian models, not only in meta-analysis.

To learn about cross-validation see Gelman et al 2014.

This function automatically runs K baggr models, where K is number of groups (e.g. studies), leaving out one group at a time. For each run, it calculates *expected log predictive density* (ELPD) for that group (see Gelman et al 2013). (In the logistic model, where the proportion in control group is unknown, each of the groups is divided into data for controls, which is kept for estimation, and data for treated units, which is not used for estimation but only for calculating predictive density. This is akin to fixing the baseline risk and only trying to infer the odds ratio.)

The main output is the cross-validation information criterion, or -2 times the ELPD summed over K models. (We sum the terms as we are working with logarithms.) This is related to, and often approximated by, the Watanabe-Akaike Information Criterion. When comparing models, smaller values mean a better fit.

For running more computation-intensive models, consider setting the `mc.cores` option before running loocv, e.g. `options(mc.cores = 4)` (by default baggr runs 4 MCMC chains in parallel). As a default, rstan runs "silently" (`refresh=0`). To see sampling progress, please set e.g. `loocv(data, refresh = 500)`.

Value

log predictive density value, an object of class `baggr_cv`; full model, prior values and *lpd* of each model are also returned. These can be examined by using `attributes()` function.

Author(s)

Witold Wiecek

References

Gelman, Andrew, Jessica Hwang, and Aki Vehtari. 'Understanding Predictive Information Criteria for Bayesian Models.' Statistics and Computing 24, no. 6 (November 2014): 997–1016.

See Also

loo_compare for comparison of many LOO CV results; you can print and plot output via plot.baggr_cv and print.baggr_cv

Examples

```
## Not run:
# even simple examples may take a while
cv <- loocv(schools, pooling = "partial")
print(cv)      # returns the lpd value
attributes(cv) # more information is included in the object

## End(Not run)
```

`loo_compare` *Compare LOO CV models*

Description

Given multiple loocv outputs, calculate differences in their expected log predictive density.

Usage

```
loo_compare(...)
```

Arguments

`...`	A series of `baggr_cv` objects passed as arguments, with a minimum of 2 arguments required for comparison. `baggr_cv` objects can be created via the loocv function. In instances where more than 2 arguments are passed, the first model will be compared sequentially to all other provided models. Arguments can be passed with names (see example below).

Value

Returns a series of comparisons in order of the arguments provided as Model 1 - Model N for N loocv objects provided. Model 1 corresponds to the first object passed and Model N corresponds to the Nth object passed.

See Also

loocv for fitting LOO CV objects and explanation of the procedure; loo package by Vehtari et al (available on CRAN) for a more comprehensive approach

Examples

```
## Not run:
# 2 models with more/less informative priors -- this will take a while to run
cv_1 <- loocv(schools, model = "rubin", pooling = "partial")
cv_2 <- loocv(schools, model = "rubin", pooling = "partial",
              prior_hypermean = normal(0, 5), prior_hypersd = cauchy(0,2.5))
loo_compare("Default prior"=cv_1,"Alternative prior"=cv_2)

## End(Not run)
```

`microcredit` *7 studies on effect of microcredit supply*

Description

This dataframe contains the data used in Meager (2019) to estimate hierarchical models on the data from 7 randomized controlled trials of expanding access to microcredit.

Usage

`microcredit`

Format

A data frame with 40267 rows, 7 study identifiers and 7 outcomes

Details

The columns include the group indicator which gives the name of the lead author on each of the respective studies, the value of the 6 outcome variables of most interest (consumer durables spending, business expenditures, business profit, business revenues, temptation goods spending and consumption spending) all of which are standardised to USD PPP in 2009 dollars per two weeks (these are flow variables), and finally a treatment assignment status indicator.

The dataset has not otherwise been cleaned and therefore includes NAs and other issues common to real-world datasets.

For more information on how and why these variables were chosen and standardised, see Meager (2019) or consult the associated code repository which includes the standardisation scripts: link

References

Meager, Rachael (2019) Understanding the average impact of microcredit expansions: A Bayesian hierarchical analysis of seven randomized experiments. American Economic Journal: Applied Economics, 11(1), 57-91.

`microcredit_simplified`

Simplified version of the microcredit dataset.

Description

This dataframe contains the data used in Meager (2019) to estimate hierarchical models on the data from 7 randomized controlled trials of expanding access to microcredit.

Usage

```
microcredit_simplified
```

Format

A data frame with 14224 rows, 7 study identifiers and 1 outcome

Details

The columns include the group indicator which gives the name of the lead author on each of the respective studies, the value of the household consumption spending standardised to USD PPP in 2009 dollars per two weeks (these are flow variables), and finally a treatment assignment status indicator.

The dataset has not otherwise been cleaned and therefore includes NAs and other issues common to real data.

For more information on how and why these variables were chosen and standardised, see Meager (2019) or consult the associated code repository: link

This dataset includes only complete cases and only the consumption outcome variable.

References

Meager, Rachael (2019) Understanding the average impact of microcredit expansions: A Bayesian hierarchical analysis of seven randomized experiments. American Economic Journal: Applied Economics, 11(1), 57-91.

`mint` *"Mean and interval" function, including other summaries, calculated for matrix (by column) or vector*

Description

This function is just a convenient shorthand for getting typical summary statistics.

Usage

```
mint(y, int = 0.95, digits = NULL, median = FALSE, sd = FALSE)
```

Arguments

`y`	matrix or a vector; for matrices, `mint` is done by-column
`int`	probability interval (default is 95 percent) to calculate
`digits`	number of significant digits to round values by.
`median`	return median value?
`sd`	return SD?

Examples

```
mint(rnorm(100, 12, 5))
```

`mutau_cor` *Correlation between mu and tau in a baggr model*

Description

Correlation between mu and tau in a baggr model

Usage

```
mutau_cor(bg, summary = FALSE, interval = 0.95)
```

Arguments

`bg`	a baggr model where `model = "mutau"`
`summary`	logical; if TRUE returns summary statistics as explained below.
`interval`	uncertainty interval width (numeric between 0 and 1), if summarising

Value

a vector of values

`plot.baggr` *Plotting method for baggr outputs*

Description

Using generic `plot()` on `baggr` output invokes `baggr_plot` visual. See therein for customisation options. Note that plot output is `ggplot2` object.‘

Usage

```
## S3 method for class 'baggr'
plot(x, ...)
```

Arguments

`x`	object of class `baggr`
`...`	optional arguments, see `baggr_plot`

Value

ggplot2 object from `baggr_plot`

Author(s)

Witold Wiecek

`plot.baggr_compare` *Plot method for baggr_compare models*

Description

Allows plots that compare multiple baggr models that were passed for comparison purposes to baggr compare or run automatically by baggr_compare

Usage

```
## S3 method for class 'baggr_compare'
plot(
  x,
  compare = x$compare,
  style = "areas",
  grid_models = FALSE,
  grid_parameters = TRUE,
  prob = x$prob,
  hyper = TRUE,
```

```
  transform = NULL,
  order = F,
  vline = FALSE,
  add_values = FALSE,
  values_digits = 2,
  values_size = 4,
  ...
)
```

Arguments

`x`	baggr_compare model to plot
`compare`	When plotting, choose between comparison of `"groups"` (default), `"hyperpars"` (to omit group-specific estimates) or (predicted) `"effects"`. The `"groups"` option is not available when `what = "prior"`.
`style`	What kind of plot to display (if `grid_models = TRUE`), passed to the `style` argument in baggr_plot.
`grid_models`	If `FALSE` (default), generate a single comparison plot; if `TRUE`, display each model (using individual baggr_plot's) side-by-side.
`grid_parameters`	if `TRUE`, uses `ggplot`-style facetting when plotting models with many parameters (especially `"quantiles"`, `"sslab"`); if `FALSE`, returns separate plot for each parameter
`prob`	Width of uncertainty interval (defaults to 95%)
`hyper`	Whether to plot pooled treatment effect in addition to group treatment effects when `compare = "groups"`
`transform`	a function (e.g. exp(), log()) to apply to the values of group (and hyper, if hyper=TRUE) effects before plotting
`order`	Whether to sort by median treatment effect by group. If yes, medians from the model with largest range of estimates are used for sorting. If not, groups are shown alphabetically.
`vline`	logical; show vertical line through 0 in the plot?
`add_values`	logical; if TRUE, values will be printed next to the plot, in a style that's similar to what is done for forest plots
`values_digits`	number of significant digits to use when printing values,
`values_size`	size of font for the values, if `add_values == TRUE`
`...`	ignored for now, may be used in the future

`plot.baggr_cv` *Plotting method for results of baggr LOO analyses*

Description

Plotting method for results of baggr LOO analyses

Usage

```
## S3 method for class 'baggr_cv'
plot(x, y, ..., add_values = TRUE)
```

Arguments

`x`	output from loocv that has `return_models` = `TRUE`
`y`	Unused, ignore
`...`	Unused, ignore
`add_values`	logical; if `TRUE`, values of *elpd* are printed next to each study

Value

`ggplot2` plot in similar style to baggr_compare default plots

`plot_quantiles` *plot quantiles*

Description

Plot results for baggr quantile models. Displays results facetted per group. Results are `ggplot2` plots and can be modified.

Usage

```
plot_quantiles(fit, ncol, hline = TRUE)
```

Arguments

`fit`	an object of class `baggr`
`ncol`	number of columns for the plot; defaults to half of number of groups
`hline`	logical; plots a line through 0

Value

ggplot2 object

Examples

```
## Not run:
bg <- baggr(microcredit_simplified, model = "quantiles",
            quantiles = c(0.25, 0.50, 0.75),
            iter = 1000, refresh = 0,
            outcome = "consumption")
#vanilla plot
plot_quantiles(bg)[[1]]
plot_quantiles(bg, hline = TRUE)[[2]] +
  ggplot2::coord_cartesian(ylim = c(-2, 5)) +
  ggplot2::ggtitle("Works like a ggplot2 plot!")

## End(Not run)
```

`pooling` *Pooling metrics and related statistics for baggr*

Description

Compute statistics relating to pooling in a given baggr meta-analysis model returns statistics, for either the entire model or individual groups, such as pooling statistic by Gelman & Pardoe (2006), *I-squared*, *H-squared*, or study weights; `heterogeneity` is a shorthand for `pooling(type = "total")` `weights` is shorthand for `pooling(metric = "weights")`

Usage

```
pooling(
  bg,
  metric = c("pooling", "isq", "hsq", "weights"),
  type = c("groups", "total"),
  summary = TRUE
)

heterogeneity(
  bg,
  metric = c("pooling", "isq", "hsq", "weights"),
  summary = TRUE
)

## S3 method for class 'baggr'
weights(object, ...)
```

Arguments

bg	a baggr model

`metric`	`"pooling"` for Gelman & Pardoe statistic *P*, `"isq"` for I-squared statistic (*1-P*, Higgins & Thompson, 2002) `"hsq"` for H squared statistic (*1/P*, ibid.); `"weights"` for study weights; also see *Details*
`type`	In `pooling` calculation is done for each of the `"groups"` (default) or for `"total"` hypereffect(s).
`summary`	logical; if `FALSE` a whole vector of pooling values is returned, otherwise only the means and intervals
`object`	baggr model for which to calculate group (study) weights
`...`	Unused, please ignore.

Details

Pooling statistic (Gelman & Pardoe, 2006) describes the extent to which group-level estimates of treatment effect are "pooled" toward average treatment effect in the meta-analysis model. If `pooling = "none"` or `"full"` (which you specify when calling baggr), then the values are always 0 or 1, respectively. If `pooling = "partial"`, the value is somewhere between 0 and 1. We can distinguish between pooling of individual groups and overall pooling in the model.

In many contexts, i.e. medical statistics, it is typical to report *1-P*, called I^2 (see Higgins and Thompson, 2002; sometimes another statistic, $H^2 = 1/P$, is used). Higher values of *I-squared* indicate higher heterogeneity; Von Hippel (2015) provides useful details for *I-squared* calculations (and some issues related to it, especially in frequentist models). See Gelman & Pardoe (2006) Section 1.1 for a short explanation of how R^2 statistic relates to the pooling metric.

Group pooling

This is the calculation done by `pooling()` if `type = "groups"` (default). In a partial pooling model (see baggr and above), group *k* (e.g. study) has standard error of treatment effect estimate, se_k. The treatment effect (across *k* groups) is variable across groups, with hyper-SD parameter $\sigma_(\tau)$.

The quantity of interest is ratio of variation in treatment effects to the total variation. By convention, we subtract it from 1, to obtain a *pooling metric P*.

$$p = 1 - (\sigma_(\tau)^2/(\sigma_(\tau)^2 + se_k^2))$$

- If $p < 0.5$, the variation across studies is higher than variation within studies.
- Values close to 1 indicate nearly full pooling. Variation across studies dominates.
- Values close to 0 indicate no pooling. Variation within studies dominates.

Note that, since σ_{τ}^2 is a Bayesian parameter (rather than a single fixed value), *P* is also a parameter. It is typical for *P* to have very high dispersion, as in many cases we cannot precisely estimate σ_{τ}. To obtain samples from the distribution of *P* (rather than summarised values), set `summary=FALSE`.

Study weights

Contributions of each group (e.g. each study) to the mean meta-analysis estimate can be calculated by calculating for each study *w_k* the inverse of sum of group-specific SE squared and between-study variation. To obtain weights, this vector (across all studies) has to be normalised to 1, i.e. *w_k/sum(w_k)* for each *k*.

SE is typically treated as a fixed quantity (and usually reported on the reported point estimate), but between-study variance is a model parameter, hence the weights themselves are also random variables.

Overall pooling in the model

Typically researchers want to report a single measure from the model, relating to heterogeneity across groups. This is calculated by either `pooling(mymodel, type = "total")` or simply `heterogeneity(mymodel)`

Formulae for the calculations below are provided in main package vignette and almost analogous to the group calculation above, but using mean variance across all studies. In other words, pooling P is simply ratio of the expected within-study variance term to total variance.

The typical study variance is calculated following Eqn. (1) and (9) in Higgins and Thompson (see References). We use this formulation to make our pooling and I^2 comparable with other meta-analysis implementations, but users should be aware that this is only one possibility for calculating that "typical" within-study variance.

Same as for group-specific estimates, P is a Bayesian parameter and its dispersion can be high.

Value

Matrix with mean and intervals for chosen pooling metric, each row corresponding to one meta-analysis group.

References

Gelman, Andrew, and Iain Pardoe. "Bayesian Measures of Explained Variance and Pooling in Multilevel (Hierarchical) Models." *Technometrics 48, no. 2 (May 2006): 241-51.*

Higgins, Julian P. T., and Simon G. Thompson. "Quantifying Heterogeneity in a Meta-Analysis." *Statistics in Medicine, vol. 21, no. 11, June 2002, pp. 1539-58.*

Hippel, Paul T von. "The Heterogeneity Statistic I2 Can Be Biased in Small Meta-Analyses." *BMC Medical Research Methodology 15 (April 14, 2015).*

`prepare_ma` *Convert individual- to summary-level data in meta-analyses*

Description

Allows for one-way conversion from full to summary data or for calculation of effects for binary data. Usually used before calling baggr. Input must be pre-formatted appropriately.

Usage

```
prepare_ma(
  data,
  effect = c("mean", "logOR", "logRR", "RD"),
  rare_event_correction = 0.25,
  correction_type = c("single", "all"),
  log = FALSE,
  cfb = FALSE,
  summarise = TRUE,
  treatment = "treatment",
  baseline = NULL,
  group = "group",
  outcome = "outcome",
  pooling = FALSE
)
```

Arguments

`data`	**either** a data.frame of individual-level observations with columns for outcome (numeric), treatment (values 0 and 1) and group (numeric, character or factor); **or**, a data frame with binary data (must have columns `a`, `c`, `b/n1`, `d/n2`).
`effect`	what effect to calculate? a `mean` (and SE) of outcome in groups or (for binary data) `logOR` (odds ratio), `logRR` (risk ratio), `RD` (risk difference);
`rare_event_correction`	This correction is used when working with binary data (effect `logOR` or `logRR`) The value of correction is added to all cells in either some or all rows (groups), depending on `correction_type`. Using corrections may bias results but is the only alternative to avoid infinite values.
`correction_type`	If `"single"` then rare event correction is only applied to the particular rows that have 0 cells, if `"all"`, then to all studies
`log`	logical; log-transform the outcome variable?
`cfb`	logical; calculate change from baseline? If yes, the outcome variable is taken as a difference between values in `outcome` and `baseline` columns
`summarise`	logical; `TRUE` by default, but you can disable it to obtain converted (e.g. logged) data with columns renamed
`treatment`	name of column with treatment variable; can be binary or a factor (if using multiple treatment columns)
`baseline`	name of column with baseline variable
`group`	name of the column with grouping variable
`outcome`	name of column with outcome variable
`pooling`	Internal use only, please ignore

Details

The conversions done by this function are not typically needed and may happen automatically when `data` is given to baggr. However, this function can be used to explicitly convert from full to reduced (summarised) data without analysing it in any model. It can be useful for examining your data and generating summary tables.

If multiple operations are performed, they are taken in this order:

1. conversion to log scale,
2. calculating change from baseline,
3. summarising data (using appropriate `effect`)

Value

- If you `summarise`: a data.frame with columns for `group`, `tau` and `se.tau` (for `effect = "mean"`, also baseline means; for `"logRR"` or `"logOR"` also `a`, `b`, `c`, `d`, which correspond to typical contingency table notation, that is: `a` = events in exposed; `b` = no events in exposed, `c` = events in unexposed, `d` = no events in unexposed).
- If you do not summarise data, individual level data will be returned, but some columns may be renamed or transformed (see the arguments above).

Author(s)

Witold Wiecek

See Also

convert_inputs for how any type of data is (internally) converted into a list of Stan inputs; vignette `baggr_binary` for more details about rare event corrections

Examples

```
# Example of working with binary outcomes data
# Make up some individual-level data first:
df_rare <- data.frame(group = paste("Study", LETTERS[1:5]),
                      a = c(0, 2, 1, 3, 1), c = c(2, 2, 3, 3, 5),
                      n1i = c(120, 300, 110, 250, 95),
                      n2i = c(120, 300, 110, 250, 95))
df_rare_ind <- binary_to_individual(df_rare)
# Calculate ORs; default rare event correction will be applied
prepare_ma(df_rare_ind, effect = "logOR")
# Add 0.5 to all rows
prepare_ma(df_rare_ind, effect = "logOR",
           correction_type = "all",
           rare_event_correction = 0.5)
```

`prepare_prior` *Prepare prior values for Stan models in baggr*

Description

This is an internal function called by baggr. You can use it for debugging or to run modified models. It extracts and prepares priors passed by the user. Then, if any necessary priors are missing, it sets them automatically and notifies user about these automatic choices.

Usage

```
prepare_prior(
  prior,
  data,
  stan_data,
  model,
  pooling,
  covariates,
  quantiles = c(),
  silent = FALSE
)
```

Arguments

`prior`	`prior` argument passed from baggr call
`data`	`data` another argument in baggr
`stan_data`	list of inputs that will be used by sampler this is already pre-obtained through convert_inputs
`model`	same as in baggr
`pooling`	same as in baggr
`covariates`	same as in baggr
`quantiles`	same as in baggr
`silent`	same as in baggr

Value

A named list with prior values that can be appended to `stan_data` and passed to a Stan model.

`print.baggr` *S3 print method for objects of class* `baggr` *(model fits)*

Description

This prints a concise summary of the main baggr model features. More info is included in the summary of the model and its attributes.

Usage

```
## S3 method for class 'baggr'
print(x, exponent = FALSE, digits = 2, prob = 0.95, group, fixed = TRUE, ...)
```

Arguments

`x`	object of class `baggr`
`exponent`	if `TRUE`, results (for means) are converted to exp scale
`digits`	Number of significant digits to print.
`prob`	Width of uncertainty interval (defaults to 95%)
`group`	logical; print group effects? If unspecified, they are printed only if less than 20 groups are present
`fixed`	logical: print fixed effects?
`...`	currently unused by this package: further arguments passed to or from other methods (`print` requirement)

`print.baggr_compare` *Print method for baggr_compare models*

Description

Print method for baggr_compare models

Usage

```
## S3 method for class 'baggr_compare'
print(x, digits, ...)
```

Arguments

`x`	baggr_compare model
`digits`	number of significant digits for effect estimates
`...`	other parameters passed to print

`print.baggr_cv` *Print baggr cv objects nicely*

Description

Print baggr cv objects nicely

Usage

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

Arguments

`x`	`baggr_cv` object obtained from loocv to print
`digits`	number of digits to print
`...`	Unused, ignore

`print.compare_baggr_cv` *Print baggr_cv comparisons*

Description

Print baggr_cv comparisons

Usage

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

Arguments

`x`	baggr_cv comparison to print
`digits`	number of digits to print
`...`	additional arguments for s3 consistency

`print_dist` *Output a distribution as a string*

Description

Used for printing nicely formatted outputs when reporting results etc.

Usage

```
print_dist(dist)
```

Arguments

`dist`	distribution name, one of priors

Value

Character string like `normal(0, 10^2)`.

`priors` *Prior distributions in baggr*

Description

This page provides a list of all available distributions that can be used to specify priors in `baggr()`. These convenience functions are designed to allow the user to write the priors in the most "natural" way when implementing them in baggr. Apart from passing on the arguments, their only other role is to perform a rudimentary check if the distribution is specified correctly.

Usage

```
multinormal(location, Sigma)

lkj(shape, order = NULL)

normal(location, scale)

lognormal(mu, sigma)

student_t(nu, mu, sigma)

cauchy(location, scale)

uniform(lower, upper)
```

Arguments

`location`	Mean for normal and multivariate normal (in which case `location` is a vector), and median for Cauchy distributions
`Sigma`	Variance-covariance matrix for multivariate normal.
`shape`	Shape parameter for LKJ
`order`	Order of LKJ matrix (typically it does not need to be specified, as it is inferred directly in the model)
`scale`	SD for Normal, scale for Cauchy
`mu`	mean of ln(X) for lognormal or location for Student's generalised T
`sigma`	SD of ln(X) for lognormal or scale for Student's generalised T
`nu`	degrees of freedom for Student's generalised T
`lower`	Lower bound for Uniform
`upper`	Upper bound for Uniform

Details

The prior choice in baggr is done via distinct arguments for each type of prior, e.g. `prior_hypermean`, or a named list of several passed to `prior`. See the examples below.

Notation for priors is "plain-text", in that you can write the distributions as `normal(5,10)`, `uniform(0,100)` etc.

Different parameters admit different priors (see baggr for explanations of what the different `prior_` arguments do):

- `prior_hypermean`, `prior_control`, and `prior_beta` will take `"normal"`, `"uniform"`, `"lognormal"`, and `"cauchy"` input for scalars. For a vector hypermean (see `"mutau"` model), it will take any of these arguments and apply them independently to each component of the vector, or it can also take a `"multinormal"` argument (see the example below).
- `prior_hypersd`, `prior_control_sd`, and `prior_sigma` will take `"normal"`, `"uniform"`, and `"lognormal"` but negative parts of the distribution are truncated
- `prior_hypercor` allows `"lkj"` input (see Lewandowski *et al.*)

Author(s)

Witold Wiecek, Rachael Meager

References

Lewandowski, Daniel, Dorota Kurowicka, and Harry Joe. "Generating Random Correlation Matrices Based on Vines and Extended Onion Method." *Journal of Multivariate Analysis* 100, no. 9 (October 1, 2009): 1989-2001.

Examples

```
# (these are not the recommended priors -- for syntax illustration only)

# change the priors for 8 schools:
baggr(schools, model = "rubin", pooling = "partial",
      prior_hypermean = normal(5,5),
      prior_hypersd = normal(0,20))


# passing priors as a list
custom_priors <- list(hypercor = lkj(1), hypersd = normal(0,10),
                      hypermean = multinormal(c(0,0),matrix(c(10,3,3,10),2,2)))
microcredit_summary_data <- prepare_ma(microcredit, outcome = "consumption")
baggr(microcredit_summary_data, model = "mutau",
      pooling = "partial", prior = custom_priors)
```

`random_effects` *Extract only random (treatment) effects from a baggr model*

Description

This function is a shortcut for `group_effects(random_only=TRUE, ...)`. Note that this is different to cluster random effects in individual-level data: by random effects we mean the random component of the group-wide effect

Usage

```
random_effects(...)
```

Arguments

`...`	arguments passed to group_effects

`schools` *8 schools example*

Description

A classic example of aggregate level continuous data in Bayesian hierarchical modelling. This dataframe contains a column of estimated treatment effects of an SAT prep program implemented in 8 different schools in the US, and a column of estimated standard errors.

Usage

```
schools
```

Format

An object of class `data.frame` with 8 rows and 3 columns.

Details

See Gelman et al (1995), Chapter 5, for context and applied example.

References

Gelman, Andrew, John B. Carlin, Hal S. Stern, and Donald B. Rubin. Bayesian Data Analysis. Taylor & Francis, 1995.

`set_prior_val` *Add prior values to Stan input for baggr*

Description

Add prior values to Stan input for baggr

Usage

```
set_prior_val(target, name, prior, p = 1, to_array = FALSE)
```

Arguments

`target`	list object (Stan input) to which prior will be added
`name`	prior name, like `hypermean`, `hypersd`, `hypercor`
`prior`	one of prior distributions allowed by baggr like normal
`p`	number of repeats of the prior, i.e. when P i.i.d. priors are set for P dimensional parameter as in "mu & tau" type of model
`to_array`	for some models where `p` may be larger than 1, Stan will expect an array instead of a numeric (even when p == 1), so for compatibiliy we return `fam` as an array type

---

`single_comp_plot` *Plot single comparison ggplot in* `baggr_compare` *style*

Description

Plot single comparison ggplot in `baggr_compare` style

Usage

```
single_comp_plot(
  df,
  title = "",
  legend = "top",
  ylab = "",
  grid = F,
  points = FALSE,
  add_values = FALSE,
  values_digits = 1,
  values_size = 4
)
```

Arguments

`df`	data.frame with columns `group`, `median`, `lci`, `uci`, `model` (character or factor listing compared models) and, optionally, `parameter` (character or factor with name of parameter)
`title`	`ggtitle` argument passed to ggplot
`legend`	`legend.position` argument passed to ggplot
`ylab`	Y axis label
`grid`	logical; if `TRUE`, facets the plot by values in the `parameter` column
`points`	you can optionally specify a (`numeric`) column that has values of points to be plotted next to intervals
`add_values`	logical; if `TRUE`, values will be printed next to the plot, in a style that's similar to what is done for forest plots
`values_digits`	number of significant digits to use when printing values,
`values_size`	size of font for the values, if `add_values` == `TRUE`

Value

a `ggplot2` object

`treatment_effect` *Average treatment effects in a baggr model*

Description

The most general `treatment_effect` displays both hypermean and hyperSD (as a list of length 2), whereas `hypermean` and `hypersd` can be used as shorthands.

Usage

```
treatment_effect(
  bg,
  summary = FALSE,
  transform = NULL,
  interval = 0.95,
  message = TRUE
)

hypermean(
  bg,
  transform = NULL,
  interval = 0.95,
  message = FALSE,
  summary = TRUE
)

hypersd(bg, transform = NULL, interval = 0.95, message = FALSE, summary = TRUE)
```

Arguments

`bg`	a baggr model
`summary`	logical; if TRUE returns summary statistics as explained below.
`transform`	a transformation to apply to the result, should be an R function; (this is commonly used when calling `treatment_effect` from other plotting or printing functions)
`interval`	uncertainty interval width (numeric between 0 and 1), if summarising
`message`	logical; use to disable messages prompted by using with no pooling models

Functions

- `treatment_effect()`: A list with 2 vectors (corresponding to MCMC samples) `tau` (mean effect) and `sigma_tau` (SD). If `summary=TRUE`, both vectors are summarised as mean and lower/upper bounds according to `interval`
- `hypermean()`: The hypermean of a `baggr` model, shorthand for `treatment_effect(x, s=T)[[1]]`
- `hypersd()`: The hyper-SD of a `baggr` model, shorthand for `treatment_effect(x, s=T)[[2]]`

`yusuf` *Yusuf et al: beta-blockers and heart attacks*

Description

This replicates Table 6 from the famous Yusuf et al. (1985), removing one trial (Snow) that had NA observations only. The paper is notable for application of rare-event corrections, which we discuss more in package vignette `baggr_binary`.

Usage

```
yusuf
```

Format

An object of class `data.frame` with 21 rows and 5 columns.

References

Yusuf, S., Peto, R., Lewis, J., Collins, R., & Sleight, P. (1985). Beta blockade during and after myocardial infarction: An overview of the randomized trials. Progress in Cardiovascular Disease, 27(5), 335–371.

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