

Package ‘stochtree’

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Title Stochastic Tree Ensembles (XBART and BART) for Supervised Learning and Causal Inference

Version 0.4.2

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Description Flexible stochastic tree ensemble software.

Robust implementations of Bayesian Additive Regression Trees (BART) (Chipman, George, McCulloch (2010) <[doi:10.1214/09-AOAS285](https://doi.org/10.1214/09-AOAS285)>) for supervised learning and Bayesian Causal Forests (BCF) (Hahn, Murray, Carvalho (2020) <[doi:10.1214/19-BA1195](https://doi.org/10.1214/19-BA1195)>) for causal inference. Enables model serialization and parallel sampling and provides a low-level interface for custom stochastic forest samplers. Includes the grow-from-root algorithm for accelerated forest sampling (He and Hahn (2021) <[doi:10.1080/01621459.2021.1942012](https://doi.org/10.1080/01621459.2021.1942012)>), a log-linear leaf model for forest-based heteroskedasticity (Murray (2020) <[doi:10.1080/01621459.2020.1813587](https://doi.org/10.1080/01621459.2020.1813587)>), and the cloglog BART model of Alam and Linero (2025) <[doi:10.48550/arXiv.2502.00606](https://doi.org/10.48550/arXiv.2502.00606)> for ordinal outcomes.

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BugReports <https://github.com/StochasticTree/stochtree/issues>

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stochtree-package	<i>stochtree: Stochastic Tree Ensembles (XBART and BART) for Supervised Learning and Causal Inference</i>
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Description

Flexible stochastic tree ensemble software. Robust implementations of Bayesian Additive Regression Trees (BART) (Chipman, George, McCulloch (2010) [doi:10.1214/09AOAS285](https://doi.org/10.1214/09AOAS285)) for supervised learning and Bayesian Causal Forests (BCF) (Hahn, Murray, Carvalho (2020) [doi:10.1214/19BA1195](https://doi.org/10.1214/19BA1195)) for causal inference. Enables model serialization and parallel sampling and provides a low-level interface for custom stochastic forest samplers. Includes the grow-from-root algorithm for accelerated forest sampling (He and Hahn (2021) [doi:10.1080/01621459.2021.1942012](https://doi.org/10.1080/01621459.2021.1942012)), a log-linear leaf model for forest-based heteroskedasticity (Murray (2020) [doi:10.1080/01621459.2020.1813587](https://doi.org/10.1080/01621459.2020.1813587)), and the cloglog BART model of Alam and Linero (2025) [doi:10.48550/arXiv.2502.00606](https://doi.org/10.48550/arXiv.2502.00606) for ordinal outcomes.

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See Also

Useful links:

- <https://stochtree.ai/>
- <https://github.com/StochasticTree/stochtree>
- Report bugs at <https://github.com/StochasticTree/stochtree/issues>

bart

Run BART for Supervised Learning

Description

Run the BART algorithm for supervised learning.

Usage

```
bart(  
  X_train,  
  y_train,  
  leaf_basis_train = NULL,  
  rfx_group_ids_train = NULL,  
  rfx_basis_train = NULL,  
  X_test = NULL,  
  leaf_basis_test = NULL,  
  rfx_group_ids_test = NULL,  
  rfx_basis_test = NULL,  
  observation_weights = NULL,  
  num_gfr = 5,  
  num_burnin = 0,  
  num_mcmc = 100,  
  previous_model_json = NULL,  
  previous_model_warmstart_sample_num = NULL,  
  general_params = list(),  
  mean_forest_params = list(),  
  variance_forest_params = list(),  
  random_effects_params = list()  
)
```

Arguments

<code>X_train</code>	Covariates used to split trees in the ensemble. May be provided either as a dataframe or a matrix. Matrix covariates will be assumed to be all numeric. Covariates passed as a dataframe will be preprocessed based on the variable types (e.g. categorical columns stored as unordered factors will be one-hot encoded, categorical columns stored as ordered factors will be passed as integers to the core algorithm, along with the metadata that the column is ordered categorical).
<code>y_train</code>	Outcome to be modeled by the ensemble.
<code>leaf_basis_train</code>	(Optional) Bases used to define a regression model $y \sim W$ in each leaf of each regression tree. By default, BART assumes constant leaf node parameters, implicitly regressing on a constant basis of ones (i.e. $y \sim 1$).
<code>rfx_group_ids_train</code>	(Optional) Group labels used for an additive random effects model.
<code>rfx_basis_train</code>	(Optional) Basis for "random-slope" regression in an additive random effects model. If <code>rfx_group_ids_train</code> is provided with a regression basis, an intercept-only random effects model will be estimated.
<code>X_test</code>	(Optional) Test set of covariates used to define "out of sample" evaluation data. May be provided either as a dataframe or a matrix, but the format of <code>X_test</code> must be consistent with that of <code>X_train</code> .
<code>leaf_basis_test</code>	(Optional) Test set of bases used to define "out of sample" evaluation data. While a test set is optional, the structure of any provided test set must match that of the training set (i.e. if both <code>X_train</code> and <code>leaf_basis_train</code> are provided, then a test set must consist of <code>X_test</code> and <code>leaf_basis_test</code> with the same number of columns).
<code>rfx_group_ids_test</code>	(Optional) Test set group labels used for an additive random effects model. We do not currently support (but plan to in the near future), test set evaluation for group labels that were not in the training set.
<code>rfx_basis_test</code>	(Optional) Test set basis for "random-slope" regression in additive random effects model.
<code>observation_weights</code>	(Optional) Numeric vector of observation weights of length <code>nrow(X_train)</code> . Weights are applied as $y_i \sim N(\mu(X_i), \sigma^2 / w_i)$, so larger weights increase an observation's influence on the fit. All weights must be non-negative. Default: NULL (all observations equally weighted). Compatible with Gaussian (continuous/identity) and probit outcome models; not compatible with cloglog link functions. Note: these are referred to internally in the C++ layer as "variance weights" (<code>var_weights</code>), since they scale the residual variance.
<code>num_gfr</code>	Number of "warm-start" iterations run using the grow-from-root algorithm (He and Hahn, 2021). Default: 5.
<code>num_burnin</code>	Number of "burn-in" iterations of the MCMC sampler. Default: 0.
<code>num_mcmc</code>	Number of "retained" iterations of the MCMC sampler. Default: 100.

`previous_model_json`

(Optional) JSON string containing a previous BART model. This can be used to "continue" a sampler interactively after inspecting the samples or to run parallel chains "warm-started" from existing forest samples. Default: NULL.

`previous_model_warmstart_sample_num`

(Optional) Sample number from `previous_model_json` that will be used to warmstart this BART sampler. One-indexed (so that the first sample is used for warm-start by setting `previous_model_warmstart_sample_num = 1`). Default: NULL. If `num_chains` in the `general_params` list is > 1 , then each successive chain will be initialized from a different sample, counting backwards from `previous_model_warmstart_sample_num`. That is, if `previous_model_warmstart_sample_num = 10` and `num_chains = 4`, then chain 1 will be initialized from sample 10, chain 2 from sample 9, chain 3 from sample 8, and chain 4 from sample 7. If `previous_model_json` is provided but `previous_model_warmstart_sample_num` is NULL, the last sample in the previous model will be used to initialize the first chain, counting backwards as noted before. If more chains are requested than there are samples in `previous_model_json`, a warning will be raised and only the last sample will be used.

`general_params` (Optional) A list of general (non-forest-specific) model parameters, each of which has a default value processed internally, so this argument list is optional.

- `cutpoint_grid_size` Maximum size of the "grid" of potential cutpoints to consider in the GFR algorithm. Default: 100.
- `standardize` Whether or not to standardize the outcome (and store the offset / scale in the model object). Default: TRUE.
- `sample_sigma2_global` Whether or not to update the σ^2 global error variance parameter based on $IG(\sigma^2_{global_shape}, \sigma^2_{global_scale})$. Default: TRUE.
- `sigma2_global_init` Starting value of global error variance parameter. Calibrated internally as $1.0 * \text{var}(y_{train})$, where `y_train` is the possibly standardized outcome, if not set.
- `sigma2_global_shape` Shape parameter in the $IG(\sigma^2_{global_shape}, \sigma^2_{global_scale})$ global error variance model. Default: 0.
- `sigma2_global_scale` Scale parameter in the $IG(\sigma^2_{global_shape}, \sigma^2_{global_scale})$ global error variance model. Default: 0.
- `variable_weights` Numeric weights reflecting the relative probability of splitting on each variable. Does not need to sum to 1 but cannot be negative. Defaults to $\text{rep}(1/\text{ncol}(X_{train}), \text{ncol}(X_{train}))$ if not set here. Note that if the propensity score is included as a covariate in either forest, its weight will default to $1/\text{ncol}(X_{train})$.
- `random_seed` Integer parameterizing the C++ random number generator. If not specified, the C++ random number generator is seeded according to `std::random_device`.
- `keep_burnin` Whether or not "burnin" samples should be included in the stored samples of forests and other parameters. Default FALSE. Ignored if `num_mcmc = 0`.
- `keep_gfr` Whether or not "grow-from-root" samples should be included in the stored samples of forests and other parameters. Default FALSE. Ignored

if `num_mcmc = 0`.

- `keep_every` How many iterations of the burned-in MCMC sampler should be run before forests and parameters are retained. Default 1. Setting `keep_every <- k` for some $k > 1$ will "thin" the MCMC samples by retaining every k -th sample, rather than simply every sample. This can reduce the autocorrelation of the MCMC samples.
- `num_chains` How many independent MCMC chains should be sampled. If `num_mcmc = 0`, this is ignored. If `num_gfr = 0`, then each chain is run from root for `num_mcmc * keep_every + num_burnin` iterations, with `num_mcmc` samples retained. If `num_gfr > 0`, each MCMC chain will be initialized from a separate GFR ensemble, with the requirement that `num_gfr >= num_chains`. Default: 1. Note that if `num_chains > 1`, the returned model object will contain samples from all chains, stored consecutively. That is, if there are 4 chains with 100 samples each, the first 100 samples will be from chain 1, the next 100 samples will be from chain 2, etc... For more detail on working with multi-chain BART models, see [the multi chain vignette](#).
- `verbose` Whether or not to print progress during the sampling loops. Default: FALSE.
- `outcome_model` A structured `OutcomeModel` object that specifies the outcome type and desired link function. This argument pre-empts the legacy (deprecated) `probit_outcome_model` option. Default: `OutcomeModel(outcome='continuous', link='identity')`.
- `probit_outcome_model` Deprecated in favor of `outcome_model`. Whether or not the outcome should be modeled as explicitly binary via a probit link. If TRUE, `y` must only contain the values 0 and 1. Default: FALSE.
- `num_threads` Number of threads to use in the GFR and MCMC algorithms, as well as prediction. If OpenMP is not available on a user's setup, this will default to 1, otherwise to the maximum number of available threads.

`mean_forest_params`

(Optional) A list of mean forest model parameters, each of which has a default value processed internally, so this argument list is optional.

- `num_trees` Number of trees in the ensemble for the conditional mean model. Default: 200. If `num_trees = 0`, the conditional mean will not be modeled using a forest, and the function will only proceed if `num_trees > 0` for the variance forest.
- `alpha` Prior probability of splitting for a tree of depth 0 in the mean model. Tree split prior combines `alpha` and `beta` via $\alpha * (1 + \text{node_depth})^{-\beta}$. Default: 0.95.
- `beta` Exponent that decreases split probabilities for nodes of depth > 0 in the mean model. Tree split prior combines `alpha` and `beta` via $\alpha * (1 + \text{node_depth})^{-\beta}$. Default: 2.
- `min_samples_leaf` Minimum allowable size of a leaf, in terms of training samples, in the mean model. Default: 5.
- `max_depth` Maximum depth of any tree in the ensemble in the mean model. Default: 10. Can be overridden with `-1` which does not enforce any depth limits on trees.

- `sample_sigma2_leaf` Whether or not to update the leaf scale variance parameter based on $IG(\text{sigma2_leaf_shape}, \text{sigma2_leaf_scale})$. Cannot (currently) be set to true if $\text{ncol}(\text{leaf_basis_train}) > 1$. Default: FALSE.
- `sigma2_leaf_init` Starting value of leaf node scale parameter. Calibrated internally as $1/\text{num_trees}$ if not set here.
- `sigma2_leaf_shape` Shape parameter in the $IG(\text{sigma2_leaf_shape}, \text{sigma2_leaf_scale})$ leaf node parameter variance model. Default: 3.
- `sigma2_leaf_scale` Scale parameter in the $IG(\text{sigma2_leaf_shape}, \text{sigma2_leaf_scale})$ leaf node parameter variance model. Calibrated internally as $0.5/\text{num_trees}$ if not set here.
- `keep_vars` Vector of variable names or column indices denoting variables that should be included in the forest. Default: NULL.
- `drop_vars` Vector of variable names or column indices denoting variables that should be excluded from the forest. Default: NULL. If both `drop_vars` and `keep_vars` are set, `drop_vars` will be ignored.
- `num_features_subsample` How many features to subsample when growing each tree for the GFR algorithm. Defaults to the number of features in the training dataset.

`variance_forest_params`

(Optional) A list of variance forest model parameters, each of which has a default value processed internally, so this argument list is optional.

- `num_trees` Number of trees in the ensemble for the conditional variance model. Default: 0. Variance is only modeled using a tree / forest if `num_trees > 0`.
- `alpha` Prior probability of splitting for a tree of depth 0 in the variance model. Tree split prior combines alpha and beta via $\text{alpha} * (1 + \text{node_depth})^{-\text{beta}}$. Default: 0.95.
- `beta` Exponent that decreases split probabilities for nodes of depth > 0 in the variance model. Tree split prior combines alpha and beta via $\text{alpha} * (1 + \text{node_depth})^{-\text{beta}}$. Default: 2.
- `min_samples_leaf` Minimum allowable size of a leaf, in terms of training samples, in the variance model. Default: 5.
- `max_depth` Maximum depth of any tree in the ensemble in the variance model. Default: 10. Can be overridden with -1 which does not enforce any depth limits on trees.
- `leaf_prior_calibration_param` Hyperparameter used to calibrate the $IG(\text{var_forest_prior_shape}, \text{var_forest_prior_scale})$ conditional error variance model. If `var_forest_prior_shape` and `var_forest_prior_scale` are not set below, this calibration parameter is used to set these values to $\text{num_trees} / \text{leaf_prior_calibration_param}^2 + 0.5$ and $\text{num_trees} / \text{leaf_prior_calibration_param}^2$, respectively. Default: 1.5.
- `var_forest_leaf_init` Starting value of root forest prediction in conditional (heteroskedastic) error variance model. Calibrated internally as $\log(0.6 * \text{var}(y_{\text{train}})) / \text{num_trees}$, where `y_train` is the possibly standardized outcome, if not set.

- `var_forest_prior_shape` Shape parameter in the IG(`var_forest_prior_shape`, `var_forest_prior_scale`) conditional error variance model (which is only sampled if `num_trees > 0`). Calibrated internally as `num_trees / leaf_prior_calibration_parameter + 0.5` if not set.
- `var_forest_prior_scale` Scale parameter in the IG(`var_forest_prior_shape`, `var_forest_prior_scale`) conditional error variance model (which is only sampled if `num_trees > 0`). Calibrated internally as `num_trees / leaf_prior_calibration_parameter` if not set.
- `keep_vars` Vector of variable names or column indices denoting variables that should be included in the forest. Default: NULL.
- `drop_vars` Vector of variable names or column indices denoting variables that should be excluded from the forest. Default: NULL. If both `drop_vars` and `keep_vars` are set, `drop_vars` will be ignored.
- `num_features_subsample` How many features to subsample when growing each tree for the GFR algorithm. Defaults to the number of features in the training dataset.

`random_effects_params`

(Optional) A list of random effects model parameters, each of which has a default value processed internally, so this argument list is optional.

- `model_spec` Specification of the random effects model. Options are "custom" and "intercept_only". If "custom" is specified, then a user-provided basis must be passed through `rfx_basis_train`. If "intercept_only" is specified, a random effects basis of all ones will be dispatched internally at sampling and prediction time. If "intercept_plus_treatment" is specified, a random effects basis that combines an "intercept" basis of all ones with the treatment variable (`Z_train`) will be dispatched internally at sampling and prediction time. Default: "custom". If "intercept_only" is specified, `rfx_basis_train` and `rfx_basis_test` (if provided) will be ignored.
- `working_parameter_prior_mean` Prior mean for the random effects "working parameter". Default: NULL. Must be a vector whose dimension matches the number of random effects bases, or a scalar value that will be expanded to a vector.
- `group_parameters_prior_mean` Prior mean for the random effects "group parameters." Default: NULL. Must be a vector whose dimension matches the number of random effects bases, or a scalar value that will be expanded to a vector.
- `working_parameter_prior_cov` Prior covariance matrix for the random effects "working parameter." Default: NULL. Must be a square matrix whose dimension matches the number of random effects bases, or a scalar value that will be expanded to a diagonal matrix.
- `group_parameter_prior_cov` Prior covariance matrix for the random effects "group parameters." Default: NULL. Must be a square matrix whose dimension matches the number of random effects bases, or a scalar value that will be expanded to a diagonal matrix.
- `variance_prior_shape` Shape parameter for the inverse gamma prior on the variance of the random effects "group parameter." Default: 1.

- `variance_prior_scale` Scale parameter for the inverse gamma prior on the variance of the random effects "group parameter." Default: 1.

Value

List of sampling outputs and a wrapper around the sampled forests (which can be used for in-memory prediction on new data, or serialized to JSON on disk).

Examples

```
n <- 100
p <- 5
X <- matrix(runif(n*p), ncol = p)
f_XW <- (
  ((0 <= X[,1]) & (0.25 > X[,1])) * (-7.5) +
  ((0.25 <= X[,1]) & (0.5 > X[,1])) * (-2.5) +
  ((0.5 <= X[,1]) & (0.75 > X[,1])) * (2.5) +
  ((0.75 <= X[,1]) & (1 > X[,1])) * (7.5)
)
noise_sd <- 1
y <- f_XW + rnorm(n, 0, noise_sd)
test_set_pct <- 0.2
n_test <- round(test_set_pct*n)
n_train <- n - n_test
test_inds <- sort(sample(1:n, n_test, replace = FALSE))
train_inds <- (1:n)[!((1:n) %in% test_inds)]
X_test <- X[test_inds,]
X_train <- X[train_inds,]
y_test <- y[test_inds]
y_train <- y[train_inds]

bart_model <- bart(X_train = X_train, y_train = y_train, X_test = X_test,
  num_gfr = 10, num_burnin = 0, num_mcmc = 10)
```

Description

BART models contains external pointers to C++ objects, which means they cannot be correctly serialized to .Rds from an R session in their default state. This group of serialization functions allow us to convert between C++ data structures and a persistent JSON representation. The `CppJson` class wraps a performant C++ JSON API, and the functions `saveBARTModelToJson` and `createBARTModelFromJson` save to and load from this format. This representation, of course, also relies on external C++ pointers, so in order to save and reload BART models across sessions, we provide two other interfaces.

`saveBARTModelToJsonString` converts a BART model to an in-memory string containing the model's JSON representation and `createBARTModelFromJsonString` converts this representation back to a BART model object.

`saveBARTModelToJsonFile` and `createBARTModelFromJsonFile` save or reload a BART model directly to / from a `.json` file.

Finally, for cases in which multiple BART models have been sampled (for instance, multiple processes run via `doParallel`), we offer `createBARTModelFromCombinedJson` and `createBARTModelFromCombinedJsonString` for loading a new combined BART model from a list of BART JSON objects / strings.

Usage

```
saveBARTModelToJson(object)

saveBARTModelToJsonFile(object, filename)

saveBARTModelToJsonString(object)

createBARTModelFromJson(json_object)

createBARTModelFromJsonFile(json_filename)

createBARTModelFromJsonString(json_string)

createBARTModelFromCombinedJson(json_object_list)

createBARTModelFromCombinedJsonString(json_string_list)
```

Arguments

<code>object</code>	Object of type <code>bartmodel</code> containing draws of a BART model and associated sampling outputs.
<code>filename</code>	String of filepath, must end in <code>".json"</code>
<code>json_object</code>	Object of type <code>CppJson</code> containing Json representation of a BART model
<code>json_filename</code>	String of filepath, must end in <code>".json"</code>
<code>json_string</code>	JSON string dump
<code>json_object_list</code>	List of objects of type <code>CppJson</code> containing Json representation of a BART model
<code>json_string_list</code>	List of JSON strings which can be parsed to objects of type <code>CppJson</code> containing Json representation of a BART model

Value

`saveBARTModelToJson` return an object of type `CppJson`. `saveBARTModelToJsonString` returns a string dump of the BART model's JSON representation. `saveBARTModelToJsonFile` returns nothing, but writes to the provided filename.

`createBARTModelFromJson`, `createBARTModelFromJsonFile`, `createBARTModelFromJsonString`, `createBARTModelFromCombinedJson`, and `createBARTModelFromCombinedJsonString` all return objects of type `bartmodel`.

Examples

```

# Generate data
n <- 100
p <- 5
X <- matrix(runif(n*p), ncol = p)
y <- X[,1] + rnorm(n, 0, 1)

# Sample BART model
bart_model <- bart(X_train = X, y_train = y, num_gfr = 0,
                  num_burnin = 0, num_mcmc = 10)

# Save to in-memory JSON
bart_json <- saveBARTModelToJson(bart_model)
# Save to JSON string
bart_json_string <- saveBARTModelToJsonString(bart_model)
# Save to JSON file
tmpjson <- tempfile(fileext = ".json")
saveBARTModelToJsonFile(bart_model, file.path(tmpjson))

# Reload BART model from in-memory JSON object
bart_model_roundtrip <- createBARTModelFromJson(bart_json)
# Reload BART model from JSON string
bart_model_roundtrip <- createBARTModelFromJsonString(bart_json_string)
# Reload BART model from JSON file
bart_model_roundtrip <- createBARTModelFromJsonFile(file.path(tmpjson))
unlink(tmpjson)
# Reload BART model from list of JSON objects
bart_model_roundtrip <- createBARTModelFromCombinedJson(list(bart_json))
# Reload BART model from list of JSON strings
bart_model_roundtrip <- createBARTModelFromCombinedJsonString(list(bart_json_string))

```

bcf

Run BCF for Causal Effect Estimation

Description

Run the Bayesian Causal Forest (BCF) algorithm for regularized causal effect estimation.

Usage

```

bcf(
  X_train,
  Z_train,
  y_train,
  propensity_train = NULL,
  rfx_group_ids_train = NULL,
  rfx_basis_train = NULL,
  X_test = NULL,

```

```

Z_test = NULL,
propensity_test = NULL,
rfx_group_ids_test = NULL,
rfx_basis_test = NULL,
observation_weights = NULL,
num_gfr = 5,
num_burnin = 0,
num_mcmc = 100,
previous_model_json = NULL,
previous_model_warmstart_sample_num = NULL,
general_params = list(),
prognostic_forest_params = list(),
treatment_effect_forest_params = list(),
variance_forest_params = list(),
random_effects_params = list()
)

```

Arguments

<code>X_train</code>	Covariates used to split trees in the ensemble. May be provided either as a dataframe or a matrix. Matrix covariates will be assumed to be all numeric. Covariates passed as a dataframe will be preprocessed based on the variable types (e.g. categorical columns stored as unordered factors will be one-hot encoded, categorical columns stored as ordered factors will be passed as integers to the core algorithm, along with the metadata that the column is ordered categorical).
<code>Z_train</code>	Vector of (continuous or binary) treatment assignments.
<code>y_train</code>	Outcome to be modeled by the ensemble.
<code>propensity_train</code>	(Optional) Vector of propensity scores. If not provided, this will be estimated from the data. If <code>NULL</code> and <code>previous_model_json</code> is provided with an internally estimated propensity model, that model's propensity estimates are re-used rather than re-fitted.
<code>rfx_group_ids_train</code>	(Optional) Group labels used for an additive random effects model.
<code>rfx_basis_train</code>	(Optional) Basis for "random-slope" regression in an additive random effects model. If <code>rfx_group_ids_train</code> is provided with a regression basis, an intercept-only random effects model will be estimated.
<code>X_test</code>	(Optional) Test set of covariates used to define "out of sample" evaluation data. May be provided either as a dataframe or a matrix, but the format of <code>X_test</code> must be consistent with that of <code>X_train</code> .
<code>Z_test</code>	(Optional) Test set of (continuous or binary) treatment assignments.
<code>propensity_test</code>	(Optional) Vector of propensity scores. If not provided, this will be estimated from the data.

<code>rfx_group_ids_test</code>	(Optional) Test set group labels used for an additive random effects model. We do not currently support (but plan to in the near future), test set evaluation for group labels that were not in the training set.
<code>rfx_basis_test</code>	(Optional) Test set basis for "random-slope" regression in additive random effects model.
<code>observation_weights</code>	(Optional) Numeric vector of observation weights of length <code>nrow(X_train)</code> . Weights are applied as $y_i - \sim N(\mu(X_i), \sigma^2 / w_i)$, so larger weights increase an observation's influence on the fit. All weights must be non-negative. Default: NULL (all observations equally weighted). Applied to both the prognostic and treatment effect forests. Compatible with Gaussian (continuous/identity) and probit outcome models; not compatible with cloglog link functions.
<code>num_gfr</code>	Number of "warm-start" iterations run using the grow-from-root algorithm (He and Hahn, 2021). Default: 5.
<code>num_burnin</code>	Number of "burn-in" iterations of the MCMC sampler. Default: 0.
<code>num_mcmc</code>	Number of "retained" iterations of the MCMC sampler. Default: 100.
<code>previous_model_json</code>	(Optional) JSON string containing a previous BCF model. This can be used to "continue" a sampler interactively after inspecting the samples or to run parallel chains "warm-started" from existing forest samples. If the previous model used an internally estimated propensity score (i.e. <code>propensity_train</code> was not supplied to that run), the fitted propensity model is carried forward and re-used rather than being re-estimated. This ensures that multi-chain warm-starts remain consistent with the propensity scores used in the initial run. Default: NULL.
<code>previous_model_warmstart_sample_num</code>	(Optional) Sample number from <code>previous_model_json</code> that will be used to warmstart this BCF sampler. One-indexed (so that the first sample is used for warm-start by setting <code>previous_model_warmstart_sample_num = 1</code>). Default: NULL. If <code>num_chains</code> in the <code>general_params</code> list is > 1 , then each successive chain will be initialized from a different sample, counting backwards from <code>previous_model_warmstart_sample_num</code> . That is, if <code>previous_model_warmstart_sample_num = 10</code> and <code>num_chains = 4</code> , then chain 1 will be initialized from sample 10, chain 2 from sample 9, chain 3 from sample 8, and chain 4 from sample 7. If <code>previous_model_json</code> is provided but <code>previous_model_warmstart_sample_num</code> is NULL, the last sample in the previous model will be used to initialize the first chain, counting backwards as noted before. If more chains are requested than there are samples in <code>previous_model_json</code> , a warning will be raised and only the last sample will be used.
<code>general_params</code>	(Optional) A list of general (non-forest-specific) model parameters, each of which has a default value processed internally, so this argument list is optional. <ul style="list-style-type: none"> <code>cutpoint_grid_size</code> Maximum size of the "grid" of potential cutpoints to consider in the GFR algorithm. Default: 100. <code>standardize</code> Whether or not to standardize the outcome (and store the offset / scale in the model object). Default: TRUE.

- `sample_sigma2_global` Whether or not to update the σ^2 global error variance parameter based on $\text{IG}(\text{sigma2_global_shape}, \text{sigma2_global_scale})$. Default: TRUE.
- `sigma2_global_init` Starting value of global error variance parameter. Calibrated internally as $1.0 \cdot \text{var}((y_{\text{train}} - \text{mean}(y_{\text{train}})) / \text{sd}(y_{\text{train}}))$ if not set.
- `sigma2_global_shape` Shape parameter in the $\text{IG}(\text{sigma2_global_shape}, \text{sigma2_global_scale})$ global error variance model. Default: 0.
- `sigma2_global_scale` Scale parameter in the $\text{IG}(\text{sigma2_global_shape}, \text{sigma2_global_scale})$ global error variance model. Default: 0.
- `variable_weights` Numeric weights reflecting the relative probability of splitting on each variable. Does not need to sum to 1 but cannot be negative. Defaults to $\text{rep}(1/\text{ncol}(X_{\text{train}}), \text{ncol}(X_{\text{train}}))$ if not set here. Note that if the propensity score is included as a covariate in either forest, its weight will default to $1/\text{ncol}(X_{\text{train}})$. A workaround if you wish to provide a custom weight for the propensity score is to include it as a column in `X_train` and then set `propensity_covariate` to 'none' adjust `keep_vars` accordingly for the prognostic or `treatment_effect` forests.
- `propensity_covariate` Whether to include the propensity score as a covariate in either or both of the forests. Enter "none" for neither, "prognostic" for the prognostic forest, "treatment_effect" for the treatment forest, and "both" for both forests. If this is not "none" and a propensity score is not provided, it will be estimated from $(X_{\text{train}}, Z_{\text{train}})$ using `stochtree::bart()`. Default: "mu".
- `adaptive_coding` Whether or not to use an "adaptive coding" scheme in which a binary treatment variable is not coded manually as (0,1) or (-1,1) but learned via parameters `b_0` and `b_1` that attach to the outcome model $[b_0 (1-Z) + b_1 Z] \tau(X)$. This is ignored when `Z` is not binary. Default: FALSE.
- `control_coding_init` Initial value of the "control" group coding parameter. This is ignored when `Z` is not binary. Default: -0.5.
- `treated_coding_init` Initial value of the "treatment" group coding parameter. This is ignored when `Z` is not binary. Default: 0.5.
- `rfx_prior_var` Prior on the (diagonals of the) covariance of the additive group-level random regression coefficients. Must be a vector of length $\text{ncol}(\text{rfx_basis_train})$. Default: $\text{rep}(1, \text{ncol}(\text{rfx_basis_train}))$
- `random_seed` Integer parameterizing the C++ random number generator. If not specified, the C++ random number generator is seeded according to `std::random_device`.
- `keep_burnin` Whether or not "burnin" samples should be included in the stored samples of forests and other parameters. Default FALSE. Ignored if `num_mcmc = 0`.
- `keep_gfr` Whether or not "grow-from-root" samples should be included in the stored samples of forests and other parameters. Default FALSE. Ignored if `num_mcmc = 0`.
- `keep_every` How many iterations of the burned-in MCMC sampler should be run before forests and parameters are retained. Default 1. Setting `keep_every`

<- k for some $k > 1$ will "thin" the MCMC samples by retaining every k-th sample, rather than simply every sample. This can reduce the autocorrelation of the MCMC samples.

- `num_chains` How many independent MCMC chains should be sampled. If `num_mcmc = 0`, this is ignored. If `num_gfr = 0`, then each chain is run from root for `num_mcmc * keep_every + num_burnin` iterations, with `num_mcmc` samples retained. If `num_gfr > 0`, each MCMC chain will be initialized from a separate GFR ensemble, with the requirement that `num_gfr >= num_chains`. Default: 1. Note that if `num_chains > 1`, the returned model object will contain samples from all chains, stored consecutively. That is, if there are 4 chains with 100 samples each, the first 100 samples will be from chain 1, the next 100 samples will be from chain 2, etc... For more detail on working with multi-chain BCF models, see [the multi chain vignette](#).
- `verbose` Whether or not to print progress during the sampling loops. Default: FALSE.
- `outcome_model` A structured `OutcomeModel` object that specifies the outcome type and desired link function. This argument pre-empts the legacy (deprecated) `probit_outcome_model` option. Default: `OutcomeModel(outcome='continuous', link='identity')`.
- `probit_outcome_model` Deprecated in favor of `outcome_model`. Whether or not the outcome should be modeled as explicitly binary via a probit link. If TRUE, `y` must only contain the values 0 and 1. Default: FALSE.
- `num_threads` Number of threads to use in the GFR and MCMC algorithms, as well as prediction. If OpenMP is not available on a user's setup, this will default to 1, otherwise to the maximum number of available threads.

`prognostic_forest_params`

(Optional) A list of prognostic forest model parameters, each of which has a default value processed internally, so this argument list is optional.

- `num_trees` Number of trees in the ensemble for the prognostic forest. Default: 250. Must be a positive integer.
- `alpha` Prior probability of splitting for a tree of depth 0 in the prognostic forest. Tree split prior combines alpha and beta via $\alpha * (1 + \text{node_depth})^{-\beta}$. Default: 0.95.
- `beta` Exponent that decreases split probabilities for nodes of depth > 0 in the prognostic forest. Tree split prior combines alpha and beta via $\alpha * (1 + \text{node_depth})^{-\beta}$. Default: 2.
- `min_samples_leaf` Minimum allowable size of a leaf, in terms of training samples, in the prognostic forest. Default: 5.
- `max_depth` Maximum depth of any tree in the ensemble in the prognostic forest. Default: 10. Can be overridden with -1 which does not enforce any depth limits on trees.
- `variable_weights` Numeric weights reflecting the relative probability of splitting on each variable in the prognostic forest. Does not need to sum to 1 but cannot be negative. Defaults to `rep(1/ncol(X_train), ncol(X_train))` if not set here.
- `sample_sigma2_leaf` Whether or not to update the leaf scale variance parameter based on `IG(sigma2_leaf_shape, sigma2_leaf_scale)`.

- `sigma2_leaf_init` Starting value of leaf node scale parameter. Calibrated internally as $1/\text{num_trees}$ if not set here.
- `sigma2_leaf_shape` Shape parameter in the $\text{IG}(\text{sigma2_leaf_shape}, \text{sigma2_leaf_scale})$ leaf node parameter variance model. Default: 3.
- `sigma2_leaf_scale` Scale parameter in the $\text{IG}(\text{sigma2_leaf_shape}, \text{sigma2_leaf_scale})$ leaf node parameter variance model. Calibrated internally as $0.5/\text{num_trees}$ if not set here.
- `keep_vars` Vector of variable names or column indices denoting variables that should be included in the forest. Default: NULL.
- `drop_vars` Vector of variable names or column indices denoting variables that should be excluded from the forest. Default: NULL. If both `drop_vars` and `keep_vars` are set, `drop_vars` will be ignored.
- `num_features_subsample` How many features to subsample when growing each tree for the GFR algorithm. Defaults to the number of features in the training dataset.

`treatment_effect_forest_params`

(Optional) A list of treatment effect forest model parameters, each of which has a default value processed internally, so this argument list is optional.

- `num_trees` Number of trees in the ensemble for the treatment effect forest. Default: 100. Must be a positive integer.
- `alpha` Prior probability of splitting for a tree of depth 0 in the treatment effect forest. Tree split prior combines alpha and beta via $\text{alpha} \times (1 + \text{node_depth})^{-\text{beta}}$. Default: 0.25.
- `beta` Exponent that decreases split probabilities for nodes of depth > 0 in the treatment effect forest. Tree split prior combines alpha and beta via $\text{alpha} \times (1 + \text{node_depth})^{-\text{beta}}$. Default: 3.
- `min_samples_leaf` Minimum allowable size of a leaf, in terms of training samples, in the treatment effect forest. Default: 5.
- `max_depth` Maximum depth of any tree in the ensemble in the treatment effect forest. Default: 5. Can be overridden with -1 which does not enforce any depth limits on trees.
- `variable_weights` Numeric weights reflecting the relative probability of splitting on each variable in the treatment effect forest. Does not need to sum to 1 but cannot be negative. Defaults to $\text{rep}(1/\text{ncol}(X_{\text{train}}), \text{ncol}(X_{\text{train}}))$ if not set here.
- `sample_sigma2_leaf` Whether or not to update the leaf scale variance parameter based on $\text{IG}(\text{sigma2_leaf_shape}, \text{sigma2_leaf_scale})$. Cannot (currently) be set to true if $\text{ncol}(Z_{\text{train}}) > 1$. Default: FALSE.
- `sigma2_leaf_init` Starting value of leaf node scale parameter. Calibrated internally as $0.5 * \text{var}(y) / \text{num_trees}$ if not set here ($0.5 / \text{num_trees}$ if y is continuous and `standardize = TRUE` in the `general_params` list).
- `sigma2_leaf_shape` Shape parameter in the $\text{IG}(\text{sigma2_leaf_shape}, \text{sigma2_leaf_scale})$ leaf node parameter variance model. Default: 3.
- `sigma2_leaf_scale` Scale parameter in the $\text{IG}(\text{sigma2_leaf_shape}, \text{sigma2_leaf_scale})$ leaf node parameter variance model. Calibrated internally as $0.5/\text{num_trees}$ if not set here.

- `delta_max` Maximum plausible conditional distributional treatment effect (i.e. $P(Y(1) = 1 | X) - P(Y(0) = 1 | X)$) when the outcome is binary. Only used when the outcome is specified as a probit model in `general_params`. Must be > 0 and < 1 . Default: `0.9`. Ignored if `sigma2_leaf_init` is set directly, as this parameter is used to calibrate `sigma2_leaf_init`.
- `keep_vars` Vector of variable names or column indices denoting variables that should be included in the forest. Default: `NULL`.
- `drop_vars` Vector of variable names or column indices denoting variables that should be excluded from the forest. Default: `NULL`. If both `drop_vars` and `keep_vars` are set, `drop_vars` will be ignored.
- `num_features_subsample` How many features to subsample when growing each tree for the GFR algorithm. Defaults to the number of features in the training dataset.
- `sample_intercept` Whether to sample a global treatment effect intercept `tau_0` so the full CATE is $\tau_0 + \tau(X)$. Default: `TRUE`. Compatible with `adaptive_coding = TRUE`, in which case the recoded treatment basis is used.
- `tau_0_prior_var` Variance of the normal prior on `tau_0` (a scalar applied to each treatment dimension independently). Auto-calibrated to outcome variance when `NULL` and outcome is continuous. Only used when `sample_intercept = TRUE`.

`variance_forest_params`

(Optional) A list of variance forest model parameters, each of which has a default value processed internally, so this argument list is optional.

- `num_trees` Number of trees in the ensemble for the conditional variance model. Default: `0`. Variance is only modeled using a tree / forest if `num_trees > 0`.
- `alpha` Prior probability of splitting for a tree of depth 0 in the variance model. Tree split prior combines `alpha` and `beta` via $\alpha * (1 + \text{node_depth})^{-\beta}$. Default: `0.95`.
- `beta` Exponent that decreases split probabilities for nodes of depth > 0 in the variance model. Tree split prior combines `alpha` and `beta` via $\alpha * (1 + \text{node_depth})^{-\beta}$. Default: `2`.
- `min_samples_leaf` Minimum allowable size of a leaf, in terms of training samples, in the variance model. Default: `5`.
- `max_depth` Maximum depth of any tree in the ensemble in the variance model. Default: `10`. Can be overridden with `-1` which does not enforce any depth limits on trees.
- `leaf_prior_calibration_param` Hyperparameter used to calibrate the `IG(var_forest_prior_shape, var_forest_prior_scale)` conditional error variance model. If `var_forest_prior_shape` and `var_forest_prior_scale` are not set below, this calibration parameter is used to set these values to $\text{num_trees} / \text{leaf_prior_calibration_param}^2 + 0.5$ and $\text{num_trees} / \text{leaf_prior_calibration_param}^2$, respectively. Default: `1.5`.
- `variance_forest_init` Starting value of root forest prediction in conditional (heteroskedastic) error variance model. Calibrated internally as

$\log(0.6 * \text{var}((y_{\text{train}} - \text{mean}(y_{\text{train}})) / \text{sd}(y_{\text{train}}))) / \text{num_trees}$ if not set.

- `var_forest_prior_shape` Shape parameter in the $\text{IG}(\text{var_forest_prior_shape}, \text{var_forest_prior_scale})$ conditional error variance model (which is only sampled if `num_trees > 0`). Calibrated internally as `num_trees / 1.5^2 + 0.5` if not set.
- `var_forest_prior_scale` Scale parameter in the $\text{IG}(\text{var_forest_prior_shape}, \text{var_forest_prior_scale})$ conditional error variance model (which is only sampled if `num_trees > 0`). Calibrated internally as `num_trees / 1.5^2` if not set.
- `keep_vars` Vector of variable names or column indices denoting variables that should be included in the forest. Default: NULL.
- `drop_vars` Vector of variable names or column indices denoting variables that should be excluded from the forest. Default: NULL. If both `drop_vars` and `keep_vars` are set, `drop_vars` will be ignored.
- `num_features_subsample` How many features to subsample when growing each tree for the GFR algorithm. Defaults to the number of features in the training dataset.

`random_effects_params`

(Optional) A list of random effects model parameters, each of which has a default value processed internally, so this argument list is optional.

- `model_spec` Specification of the random effects model. Options are "custom", "intercept_only", and "intercept_plus_treatment". If "custom" is specified, then a user-provided basis must be passed through `rfx_basis_train`. If "intercept_only" is specified, a random effects basis of all ones will be dispatched internally at sampling and prediction time. If "intercept_plus_treatment" is specified, a random effects basis that combines an "intercept" basis of all ones with the treatment variable (`Z_train`) will be dispatched internally at sampling and prediction time. Default: "custom". If either "intercept_only" or "intercept_plus_treatment" is specified, `rfx_basis_train` and `rfx_basis_test` (if provided) will be ignored.
- `working_parameter_prior_mean` Prior mean for the random effects "working parameter". Default: NULL. Must be a vector whose dimension matches the number of random effects bases, or a scalar value that will be expanded to a vector.
- `group_parameters_prior_mean` Prior mean for the random effects "group parameters." Default: NULL. Must be a vector whose dimension matches the number of random effects bases, or a scalar value that will be expanded to a vector.
- `working_parameter_prior_cov` Prior covariance matrix for the random effects "working parameter." Default: NULL. Must be a square matrix whose dimension matches the number of random effects bases, or a scalar value that will be expanded to a diagonal matrix.
- `group_parameter_prior_cov` Prior covariance matrix for the random effects "group parameters." Default: NULL. Must be a square matrix whose dimension matches the number of random effects bases, or a scalar value that will be expanded to a diagonal matrix.

- `variance_prior_shape` Shape parameter for the inverse gamma prior on the variance of the random effects "group parameter." Default: 1.
- `variance_prior_scale` Scale parameter for the inverse gamma prior on the variance of the random effects "group parameter." Default: 1.

Value

List of sampling outputs and a wrapper around the sampled forests (which can be used for in-memory prediction on new data, or serialized to JSON on disk).

Examples

```
n <- 500
p <- 5
X <- matrix(runif(n*p), ncol = p)
mu_x <- (
  ((0 <= X[,1]) & (0.25 > X[,1])) * (-7.5) +
  ((0.25 <= X[,1]) & (0.5 > X[,1])) * (-2.5) +
  ((0.5 <= X[,1]) & (0.75 > X[,1])) * (2.5) +
  ((0.75 <= X[,1]) & (1 > X[,1])) * (7.5)
)
pi_x <- (
  ((0 <= X[,1]) & (0.25 > X[,1])) * (0.2) +
  ((0.25 <= X[,1]) & (0.5 > X[,1])) * (0.4) +
  ((0.5 <= X[,1]) & (0.75 > X[,1])) * (0.6) +
  ((0.75 <= X[,1]) & (1 > X[,1])) * (0.8)
)
tau_x <- (
  ((0 <= X[,2]) & (0.25 > X[,2])) * (0.5) +
  ((0.25 <= X[,2]) & (0.5 > X[,2])) * (1.0) +
  ((0.5 <= X[,2]) & (0.75 > X[,2])) * (1.5) +
  ((0.75 <= X[,2]) & (1 > X[,2])) * (2.0)
)
Z <- rbinom(n, 1, pi_x)
noise_sd <- 1
y <- mu_x + tau_x*Z + rnorm(n, 0, noise_sd)
test_set_pct <- 0.2
n_test <- round(test_set_pct*n)
n_train <- n - n_test
test_inds <- sort(sample(1:n, n_test, replace = FALSE))
train_inds <- (1:n)[!((1:n) %in% test_inds)]
X_test <- X[test_inds,]
X_train <- X[train_inds,]
pi_test <- pi_x[test_inds]
pi_train <- pi_x[train_inds]
Z_test <- Z[test_inds]
Z_train <- Z[train_inds]
y_test <- y[test_inds]
y_train <- y[train_inds]
mu_test <- mu_x[test_inds]
mu_train <- mu_x[train_inds]
tau_test <- tau_x[test_inds]
```

```
tau_train <- tau_x[train_inds]
bcf_model <- bcf(X_train = X_train, Z_train = Z_train, y_train = y_train,
  propensity_train = pi_train, X_test = X_test, Z_test = Z_test,
  propensity_test = pi_test, num_gfr = 10,
  num_burnin = 0, num_mcmc = 10)
```

BCFSerialization *BCF Serialization Routines*

Description

BCF models contains external pointers to C++ objects, which means they cannot be correctly serialized to .Rds from an R session in their default state. These functions allow us to convert between C++ data structures and a persistent JSON representation. The CppJson class wraps a performant C++ JSON API, and the functions `saveBCFModelToJson` and `createBCFModelFromJson` save to and load from this format. This representation, of course, also relies on external C++ pointers, so in order to save and reload BCF models across sessions, we provide two other interfaces.

`saveBCFModelToJsonFile` and `createBCFModelFromJsonFile` save or reload a BCF model's JSON representation directly to / from a .json file.

`saveBCFModelToJsonString` and `createBCFModelFromJsonString` handle in-memory strings containing JSON data, which can be written to disk or passed between processes.

Finally, for cases in which multiple BCF models have been sampled (for instance, sampled in multiple processes via `doParallel`), we offer `createBCFModelFromCombinedJson` and `createBCFModelFromCombinedJsonString` for loading a new combined BCF model from a list of BCF JSON objects or strings.

Usage

```
saveBCFModelToJson(object)

saveBCFModelToJsonFile(object, filename)

saveBCFModelToJsonString(object)

createBCFModelFromJson(json_object)

createBCFModelFromJsonFile(json_filename)

createBCFModelFromJsonString(json_string)

createBCFModelFromCombinedJson(json_object_list)

createBCFModelFromCombinedJsonString(json_string_list)
```

Arguments

<code>object</code>	Object of type <code>bcfmodel</code> containing draws of a Bayesian causal forest model and associated sampling outputs.
<code>filename</code>	String of filepath, must end in ".json"
<code>json_object</code>	Object of type <code>CppJson</code> containing Json representation of a BCF model
<code>json_filename</code>	String of filepath, must end in ".json"
<code>json_string</code>	JSON string dump
<code>json_object_list</code>	List of objects of type <code>CppJson</code> containing Json representation of a BCF model
<code>json_string_list</code>	List of JSON strings which can be parsed to objects of type <code>CppJson</code> containing Json representation of a BCF model

Value

`saveBCFModelToJson` return an object of type `CppJson`. `saveBCFModelToJsonFile` returns nothing, but writes to the provided filename. `saveBCFModelToJsonString` returns a string dump of the BCF model's JSON representation.

`createBCFModelFromJson`, `createBCFModelFromJsonFile`, `createBCFModelFromJsonString`, `createBCFModelFromCombinedJson`, and `createBCFModelFromCombinedJsonString` all return objects of type `bcfmodel`.

Examples

```
# Generate data
n <- 100
p <- 5
X <- matrix(runif(n*p), ncol = p)
pi_X <- runif(n, 0.3, 0.7)
Z <- rbinom(n, p = pi_X, size = 1)
y <- X[,1] + Z + rnorm(n, 0, 1)

# Sample BCF model
bcf_model <- bcf(X_train = X, Z_train = Z, propensity_train = pi_X, y_train = y,
               num_gfr = 0, num_burnin = 0, num_mcmc = 10)

# Save to in-memory JSON
bcf_json <- saveBCFModelToJson(bcf_model)
# Save to JSON string
bcf_json_string <- saveBCFModelToJsonString(bcf_model)
# Save to JSON file
tmpjson <- tempfile(fileext = ".json")
saveBCFModelToJsonFile(bcf_model, file.path(tmpjson))

# Reload BCF model from in-memory JSON object
bcf_model_roundtrip <- createBCFModelFromJson(bcf_json)
# Reload BCF model from JSON string
bcf_model_roundtrip <- createBCFModelFromJsonString(bcf_json_string)
```

```
# Reload BCF model from JSON file
bcf_model_roundtrip <- createBCFModelFromJsonFile(file.path(tmpjson))
unlink(tmpjson)
# Reload BCF model from list of JSON objects
bcf_model_roundtrip <- createBCFModelFromCombinedJson(list(bcf_json))
# Reload BCF model from list of JSON strings
bcf_model_roundtrip <- createBCFModelFromCombinedJsonString(list(bcf_json_string))
```

calibrateInverseGammaErrorVariance

Calibrate Inverse Gamma Prior

Description

Calibrate the scale parameter on an inverse gamma prior for the global error variance as in Chipman et al (2022)

This function is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Chipman, H., George, E., Hahn, R., McCulloch, R., Pratola, M. and Sparapani, R. (2022). Bayesian Additive Regression Trees, Computational Approaches. In Wiley StatsRef: Statistics Reference Online (eds N. Balakrishnan, T. Colton, B. Everitt, W. Piegorisch, F. Ruggeri and J.L. Teugels). [doi:10.1002/9781118445112.stat08288](https://doi.org/10.1002/9781118445112.stat08288)

Usage

```
calibrateInverseGammaErrorVariance(
  y,
  X,
  W = NULL,
  nu = 3,
  quant = 0.9,
  standardize = TRUE
)
```

Arguments

y	Outcome to be modeled using BART, BCF or another nonparametric ensemble method.
X	Covariates to be used to partition trees in an ensemble or series of ensemble.
W	(Optional) Basis used to define a "leaf regression" model for each decision tree. The "classic" BART model assumes a constant leaf parameter, which is equivalent to a "leaf regression" on a basis of all ones, though it is not necessary to pass a vector of ones, here or to the BART function. Default: NULL.

nu	The shape parameter for the global error variance's IG prior. The scale parameter in the Sparapani et al (2021) parameterization is defined as $\text{nu} \times \text{lambda}$ where lambda is the output of this function. Default: 3.
quant	(Optional) Quantile of the inverse gamma prior distribution represented by a linear-regression-based overestimate of σ^2 . Default: 0.9.
standardize	(Optional) Whether or not outcome should be standardized $((y - \text{mean}(y)) / \text{sd}(y))$ before calibration of lambda. Default: TRUE.

Value

Value of lambda which determines the scale parameter of the global error variance prior ($\sigma^2 \sim \text{IG}(\text{nu}, \text{nu} \times \text{lambda})$)

Examples

```
n <- 100
p <- 5
X <- matrix(runif(n*p), ncol = p)
y <- 10*X[,1] - 20*X[,2] + rnorm(n)
nu <- 3
lambda <- calibrateInverseGammaErrorVariance(y, X, nu = nu)
sigma2hat <- mean(resid(lm(y~X))^2)
mean(var(y)/rgamma(100000, nu, rate = nu*lambda) < sigma2hat)
```

computeBARTPosteriorInterval

Compute BART Posterior Credible Intervals

Description

Compute posterior credible intervals for specified terms from a fitted BART model. Supports intervals for mean functions, variance functions, random effects, and overall outcome predictions.

Usage

```
computeBARTPosteriorInterval(
  model_object,
  terms,
  level = 0.95,
  scale = "linear",
  X = NULL,
  leaf_basis = NULL,
  rfx_group_ids = NULL,
  rfx_basis = NULL
)
```

Arguments

model_object	A fitted BART or BCF model object of class bartmodel.
terms	A character string specifying the model term(s) for which to compute intervals. Options for BART models are "mean_forest", "variance_forest", "rfx", or "y_hat".
level	A numeric value between 0 and 1 specifying the credible interval level (default is 0.95 for a 95% credible interval).
scale	(Optional) Scale of mean function predictions. Options are "linear", which returns predictions on the original scale of the mean forest / RFX terms, and "probability". scale = "probability" is only valid for models fit with a probit / cloglog links on binary or ordinal outcomes. For binary outcome models, scale = "probability" will return an interval over the probability that $y = 1$. For ordinal outcome models, scale = "probability" will return intervals over the "survival function" $P(y > k)$ for $k = 1, 2, \dots, K-1$ where K is the total number of categories. Default: "linear".
X	A matrix or data frame of covariates at which to compute the intervals. Required if the requested term depends on covariates (e.g., mean forest, variance forest, or overall predictions).
leaf_basis	An optional matrix of basis function evaluations for mean forest models with regression defined in the leaves. Required for "leaf regression" models.
rfx_group_ids	An optional vector of group IDs for random effects. Required if the requested term includes random effects.
rfx_basis	An optional matrix of basis function evaluations for random effects. Required if the requested term includes random effects.

Value

A list containing the lower and upper bounds of the credible interval for the specified term. If multiple terms are requested, a named list with intervals for each term is returned.

Examples

```
n <- 100
p <- 5
X <- matrix(rnorm(n * p), nrow = n, ncol = p)
y <- 2 * X[,1] + rnorm(n)
bart_model <- bart(y_train = y, X_train = X)
intervals <- computeBARTPosteriorInterval(
  model_object = bart_model,
  terms = c("mean_forest", "y_hat"),
  X = X,
  level = 0.90
)
```

 computeBCFPosteriorInterval

Compute BCF Posterior Credible Intervals

Description

Compute posterior credible intervals for specified terms from a fitted BCF model. Supports intervals for prognostic forests, CATE forests, variance forests, random effects, and overall mean outcome predictions.

Usage

```
computeBCFPosteriorInterval(
  model_object,
  terms,
  level = 0.95,
  scale = "linear",
  X = NULL,
  Z = NULL,
  propensity = NULL,
  rfx_group_ids = NULL,
  rfx_basis = NULL
)
```

Arguments

model_object	A fitted BCF model object of class <code>bcfmodel</code> .
terms	A character string specifying the model term(s) for which to compute intervals. Options for BCF models are "prognostic_function", "mu", "cate", "tau", "variance_forest", "rfx", or "y_hat". Note that "mu" is only different from "prognostic_function" if random effects are included with a model spec of "intercept_only" or "intercept_plus_treatment" and "tau" is only different from "cate" if random effects are included with a model spec of "intercept_plus_treatment".
level	A numeric value between 0 and 1 specifying the credible interval level (default is 0.95 for a 95% credible interval).
scale	(Optional) Scale of mean function predictions. Options are "linear", which returns predictions on the original scale of the mean forest / RFX terms, and "probability", which transforms predictions into a probability of observing $y = 1$. "probability" is only valid for models fit with a probit outcome model. Default: "linear".
X	(Optional) A matrix or data frame of covariates at which to compute the intervals. Required if the requested term depends on covariates (e.g., prognostic forest, CATE forest, variance forest, or overall predictions).
Z	(Optional) A vector or matrix of treatment assignments. Required if the requested term is "y_hat" (overall predictions).

propensity	(Optional) A vector or matrix of propensity scores. Required if the underlying model depends on user-provided propensities.
rfx_group_ids	An optional vector of group IDs for random effects. Required if the requested term includes random effects.
rfx_basis	An optional matrix of basis function evaluations for random effects. Required if the requested term includes random effects.

Value

A list containing the lower and upper bounds of the credible interval for the specified term. If multiple terms are requested, a named list with intervals for each term is returned.

Examples

```
n <- 100
p <- 5
X <- matrix(rnorm(n * p), nrow = n, ncol = p)
pi_X <- pnorm(0.5 * X[,1])
Z <- rbinom(n, 1, pi_X)
mu_X <- X[,1]
tau_X <- 0.25 * X[,2]
y <- mu_X + tau_X * Z + rnorm(n)
bcf_model <- bcf(X_train = X, Z_train = Z, y_train = y,
                 propensity_train = pi_X)
intervals <- computeBCFPosteriorInterval(
  model_object = bcf_model,
  terms = c("prognostic_function", "cate"),
  X = X,
  Z = Z,
  propensity = pi_X,
  level = 0.90
)
```

```
computeContrastBARTModel
```

Compute Contrast for BART Model

Description

Compute a contrast using a BART model by making two sets of outcome predictions and taking their difference. This function provides the flexibility to compute any contrast of interest by specifying covariates, leaf basis, and random effects bases / IDs for both sides of a two term contrast. For simplicity, we refer to the subtrahend of the contrast as the "control" or Y_0 term and the minuend of the contrast as the Y_1 term, though the requested contrast need not match the "control vs treatment" terminology of a classic two-treatment causal inference problem. We mirror the function calls and terminology of the `predict.bartmodel` function, labeling each prediction data term with a 1 to denote its contribution to the treatment prediction of a contrast and 0 to denote inclusion in the control prediction.

Only valid when there is either a mean forest or a random effects term in the BART model.

Usage

```
computeContrastBARTModel(
  object,
  X_0,
  X_1,
  leaf_basis_0 = NULL,
  leaf_basis_1 = NULL,
  rfx_group_ids_0 = NULL,
  rfx_group_ids_1 = NULL,
  rfx_basis_0 = NULL,
  rfx_basis_1 = NULL,
  type = "posterior",
  scale = "linear"
)
```

Arguments

object	Object of type bart containing draws of a regression forest and associated sampling outputs.
X_0	Covariates used for prediction in the "control" case. Must be a matrix or dataframe.
X_1	Covariates used for prediction in the "treatment" case. Must be a matrix or dataframe.
leaf_basis_0	(Optional) Bases used for prediction in the "control" case (by e.g. dot product with leaf values). Default: NULL.
leaf_basis_1	(Optional) Bases used for prediction in the "treatment" case (by e.g. dot product with leaf values). Default: NULL.
rfx_group_ids_0	(Optional) Test set group labels used for prediction from an additive random effects model in the "control" case. We do not currently support (but plan to in the near future), test set evaluation for group labels that were not in the training set. Must be a vector.
rfx_group_ids_1	(Optional) Test set group labels used for prediction from an additive random effects model in the "treatment" case. We do not currently support (but plan to in the near future), test set evaluation for group labels that were not in the training set. Must be a vector.
rfx_basis_0	(Optional) Test set basis for used for prediction from an additive random effects model in the "control" case. Must be a matrix or vector.
rfx_basis_1	(Optional) Test set basis for used for prediction from an additive random effects model in the "treatment" case. Must be a matrix or vector.
type	(Optional) Aggregation level of the contrast. Options are "mean", which averages the contrast evaluations over every draw of a BART model, and "posterior", which returns the entire matrix of posterior contrast estimates. Default: "posterior".

scale (Optional) Scale of the contrast. Options are "linear", which returns contrast of predictions on the original scale of the mean forest / RFX terms, and "probability". `scale = "probability"` is only valid for models fit with a probit / cloglog links on binary or ordinal outcomes. For binary outcome models, `scale = "probability"` will return contrasts of the probability that $y = 1$. For ordinal outcome models, `scale = "probability"` will return contrasts over the "survival function" $P(y > k)$ for $k = 1, 2, \dots, K-1$ where K is the total number of categories. Default: "linear".

Value

Contrast matrix or vector, depending on whether `type = "mean"` or `"posterior"`.

Examples

```
n <- 100
p <- 5
X <- matrix(runif(n*p), ncol = p)
W <- matrix(runif(n*1), ncol = 1)
f_XW <- (
  ((0 <= X[,1]) & (0.25 > X[,1])) * (-7.5*W[,1]) +
  ((0.25 <= X[,1]) & (0.5 > X[,1])) * (-2.5*W[,1]) +
  ((0.5 <= X[,1]) & (0.75 > X[,1])) * (2.5*W[,1]) +
  ((0.75 <= X[,1]) & (1 > X[,1])) * (7.5*W[,1])
)
noise_sd <- 1
y <- f_XW + rnorm(n, 0, noise_sd)
test_set_pct <- 0.2
n_test <- round(test_set_pct*n)
n_train <- n - n_test
test_inds <- sort(sample(1:n, n_test, replace = FALSE))
train_inds <- (1:n)[!((1:n) %in% test_inds)]
X_test <- X[test_inds,]
X_train <- X[train_inds,]
W_test <- W[test_inds,]
W_train <- W[train_inds,]
y_test <- y[test_inds]
y_train <- y[train_inds]
bart_model <- bart(X_train = X_train, leaf_basis_train = W_train, y_train = y_train,
  num_gfr = 10, num_burnin = 0, num_mcmc = 10)
contrast_test <- computeContrastBARTModel(
  bart_model,
  X_0 = X_test,
  X_1 = X_test,
  leaf_basis_0 = matrix(0, nrow = n_test, ncol = 1),
  leaf_basis_1 = matrix(1, nrow = n_test, ncol = 1),
  type = "posterior",
  scale = "linear"
)
```

`computeContrastBCFModel`*Compute Contrast for BCF Model*

Description

Compute a contrast using a BCF model by making two sets of outcome predictions and taking their difference. For simple BCF models with binary treatment, this will yield the same prediction as requesting `terms = "cate"` in the `predict.bcfmodel` function. For more general models, such as models with continuous / multivariate treatments or an additive random effects term with a coefficient on the treatment, this function provides the flexibility to compute a any contrast of interest by specifying covariates, treatment, and random effects bases and IDs for both sides of a two term contrast. For simplicity, we refer to the subtrahend of the contrast as the "control" or Y_0 term and the minuend of the contrast as the Y_1 term, though the requested contrast need not match the "control vs treatment" terminology of a classic two-arm experiment. We mirror the function calls and terminology of the `predict.bcfmodel` function, labeling each prediction data term with a 1 to denote its contribution to the treatment prediction of a contrast and 0 to denote inclusion in the control prediction.

Usage

```
computeContrastBCFModel(  
  object,  
  X_0,  
  X_1,  
  Z_0,  
  Z_1,  
  propensity_0 = NULL,  
  propensity_1 = NULL,  
  rfx_group_ids_0 = NULL,  
  rfx_group_ids_1 = NULL,  
  rfx_basis_0 = NULL,  
  rfx_basis_1 = NULL,  
  type = "posterior",  
  scale = "linear"  
)
```

Arguments

<code>object</code>	Object of type <code>bcfmodel</code> containing draws of a Bayesian causal forest model and associated sampling outputs.
<code>X_0</code>	Covariates used for prediction in the "control" case. Must be a matrix or dataframe.
<code>X_1</code>	Covariates used for prediction in the "treatment" case. Must be a matrix or dataframe.
<code>Z_0</code>	Treatments used for prediction in the "control" case. Must be a matrix or vector.

Z_1	Treatments used for prediction in the "treatment" case. Must be a matrix or vector.
propensity_0	(Optional) Propensities used for prediction in the "control" case. Must be a matrix or vector.
propensity_1	(Optional) Propensities used for prediction in the "treatment" case. Must be a matrix or vector.
rfx_group_ids_0	(Optional) Test set group labels used for prediction from an additive random effects model in the "control" case. We do not currently support (but plan to in the near future), test set evaluation for group labels that were not in the training set. Must be a vector.
rfx_group_ids_1	(Optional) Test set group labels used for prediction from an additive random effects model in the "treatment" case. We do not currently support (but plan to in the near future), test set evaluation for group labels that were not in the training set. Must be a vector.
rfx_basis_0	(Optional) Test set basis for used for prediction from an additive random effects model in the "control" case. Must be a matrix or vector.
rfx_basis_1	(Optional) Test set basis for used for prediction from an additive random effects model in the "treatment" case. Must be a matrix or vector.
type	(Optional) Aggregation level of the contrast. Options are "mean", which averages the contrast evaluations over every draw of a BCF model, and "posterior", which returns the entire matrix of posterior contrast estimates. Default: "posterior".
scale	(Optional) Scale of the contrast. Options are "linear", which returns a contrast on the original scale of the mean forest / RFX terms, and "probability", which transforms each contrast term into a probability of observing $y = 1$ before taking their difference. "probability" is only valid for models fit with a probit outcome model. Default: "linear".

Value

List of prediction matrices or single prediction matrix / vector, depending on the terms requested.

Examples

```
n <- 500
p <- 5
X <- matrix(runif(n*p), ncol = p)
mu_x <- (
  ((0 <= X[,1]) & (0.25 > X[,1])) * (-7.5) +
  ((0.25 <= X[,1]) & (0.5 > X[,1])) * (-2.5) +
  ((0.5 <= X[,1]) & (0.75 > X[,1])) * (2.5) +
  ((0.75 <= X[,1]) & (1 > X[,1])) * (7.5)
)
pi_x <- (
  ((0 <= X[,1]) & (0.25 > X[,1])) * (0.2) +
  ((0.25 <= X[,1]) & (0.5 > X[,1])) * (0.4) +
```

```

      ((0.5 <= X[,1]) & (0.75 > X[,1])) * (0.6) +
      ((0.75 <= X[,1]) & (1 > X[,1])) * (0.8)
    )
    tau_x <- (
      ((0 <= X[,2]) & (0.25 > X[,2])) * (0.5) +
      ((0.25 <= X[,2]) & (0.5 > X[,2])) * (1.0) +
      ((0.5 <= X[,2]) & (0.75 > X[,2])) * (1.5) +
      ((0.75 <= X[,2]) & (1 > X[,2])) * (2.0)
    )
    Z <- rbinom(n, 1, pi_x)
    noise_sd <- 1
    y <- mu_x + tau_x*Z + rnorm(n, 0, noise_sd)
    test_set_pct <- 0.2
    n_test <- round(test_set_pct*n)
    n_train <- n - n_test
    test_inds <- sort(sample(1:n, n_test, replace = FALSE))
    train_inds <- (1:n)[!((1:n) %in% test_inds)]
    X_test <- X[test_inds,]
    X_train <- X[train_inds,]
    pi_test <- pi_x[test_inds]
    pi_train <- pi_x[train_inds]
    Z_test <- Z[test_inds]
    Z_train <- Z[train_inds]
    y_test <- y[test_inds]
    y_train <- y[train_inds]
    mu_test <- mu_x[test_inds]
    mu_train <- mu_x[train_inds]
    tau_test <- tau_x[test_inds]
    tau_train <- tau_x[train_inds]
    bcf_model <- bcf(X_train = X_train, Z_train = Z_train, y_train = y_train,
                    propensity_train = pi_train, num_gfr = 10,
                    num_burnin = 0, num_mcmc = 10)
    tau_hat_test <- computeContrastBCFModel(
      bcf_model, X_0=X_test, X_1=X_test, Z_0=rep(0, n_test), Z_1=rep(1, n_test),
      propensity_0 = pi_test, propensity_1 = pi_test
    )
  )

```

Description

Wrapper around a C++ `nlohmann::json` object

This class is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the `stochtree`'s advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Public fields

json_ptr External pointer to a C++ nlohmann::json object
 num_forests Number of forests in the nlohmann::json object
 forest_labels Names of forest objects in the overall nlohmann::json object
 num_rfx Number of random effects terms in the nlohman::json object
 rfx_container_labels Names of rfx container objects in the overall nlohmann::json object
 rfx_mapper_labels Names of rfx label mapper objects in the overall nlohmann::json object
 rfx_groupid_labels Names of rfx group id objects in the overall nlohmann::json object

Methods**Public methods:**

- CppJson\$new()
- CppJson\$add_forest()
- CppJson\$add_random_effects()
- CppJson\$add_scalar()
- CppJson\$add_integer()
- CppJson\$add_boolean()
- CppJson\$add_string()
- CppJson\$add_vector()
- CppJson\$add_integer_vector()
- CppJson\$add_string_vector()
- CppJson\$add_list()
- CppJson\$add_string_list()
- CppJson\$get_scalar()
- CppJson\$get_integer()
- CppJson\$get_boolean()
- CppJson\$get_string()
- CppJson\$get_vector()
- CppJson\$get_integer_vector()
- CppJson\$get_string_vector()
- CppJson\$get_numeric_list()
- CppJson\$get_string_list()
- CppJson\$return_json_string()
- CppJson\$save_file()
- CppJson\$load_from_file()
- CppJson\$load_from_string()

Method new(): Create a new CppJson object.

Usage:

CppJson\$new()

Returns: A new CppJson object.

Method `add_forest()`: Convert a forest container to json and add to the current CppJson object

Usage:

```
CppJson$add_forest(forest_samples)
```

Arguments:

`forest_samples` ForestSamples R class

Returns: None

Method `add_random_effects()`: Convert a random effects container to json and add to the current CppJson object

Usage:

```
CppJson$add_random_effects(rfx_samples)
```

Arguments:

`rfx_samples` RandomEffectSamples R class

Returns: None

Method `add_scalar()`: Add a scalar to the json object under the name "field_name" (with optional subfolder "subfolder_name")

Usage:

```
CppJson$add_scalar(field_name, field_value, subfolder_name = NULL)
```

Arguments:

`field_name` The name of the field to be added to json

`field_value` Numeric value of the field to be added to json

`subfolder_name` (Optional) Name of the subfolder / hierarchy under which to place the value

Returns: None

Method `add_integer()`: Add a scalar to the json object under the name "field_name" (with optional subfolder "subfolder_name")

Usage:

```
CppJson$add_integer(field_name, field_value, subfolder_name = NULL)
```

Arguments:

`field_name` The name of the field to be added to json

`field_value` Integer value of the field to be added to json

`subfolder_name` (Optional) Name of the subfolder / hierarchy under which to place the value

Returns: None

Method `add_boolean()`: Add a boolean value to the json object under the name "field_name" (with optional subfolder "subfolder_name")

Usage:

```
CppJson$add_boolean(field_name, field_value, subfolder_name = NULL)
```

Arguments:

`field_name` The name of the field to be added to json

`field_value` Numeric value of the field to be added to json

subfolder_name (Optional) Name of the subfolder / hierarchy under which to place the value

Returns: None

Method add_string(): Add a string value to the json object under the name "field_name" (with optional subfolder "subfolder_name")

Usage:

```
CppJson$add_string(field_name, field_value, subfolder_name = NULL)
```

Arguments:

field_name The name of the field to be added to json

field_value Numeric value of the field to be added to json

subfolder_name (Optional) Name of the subfolder / hierarchy under which to place the value

Returns: None

Method add_vector(): Add a vector to the json object under the name "field_name" (with optional subfolder "subfolder_name")

Usage:

```
CppJson$add_vector(field_name, field_vector, subfolder_name = NULL)
```

Arguments:

field_name The name of the field to be added to json

field_vector Vector to be stored in json

subfolder_name (Optional) Name of the subfolder / hierarchy under which to place the value

Returns: None

Method add_integer_vector(): Add an integer vector to the json object under the name "field_name" (with optional subfolder "subfolder_name")

Usage:

```
CppJson$add_integer_vector(field_name, field_vector, subfolder_name = NULL)
```

Arguments:

field_name The name of the field to be added to json

field_vector Vector to be stored in json

subfolder_name (Optional) Name of the subfolder / hierarchy under which to place the value

Returns: None

Method add_string_vector(): Add an array to the json object under the name "field_name" (with optional subfolder "subfolder_name")

Usage:

```
CppJson$add_string_vector(field_name, field_vector, subfolder_name = NULL)
```

Arguments:

field_name The name of the field to be added to json

field_vector Character vector to be stored in json

subfolder_name (Optional) Name of the subfolder / hierarchy under which to place the value

Returns: None

Method add_list(): Add a list of vectors (as an object map of arrays) to the json object under the name "field_name"

Usage:

```
CppJson$add_list(field_name, field_list)
```

Arguments:

field_name The name of the field to be added to json

field_list List to be stored in json

Returns: None

Method add_string_list(): Add a list of vectors (as an object map of arrays) to the json object under the name "field_name"

Usage:

```
CppJson$add_string_list(field_name, field_list)
```

Arguments:

field_name The name of the field to be added to json

field_list List to be stored in json

Returns: None

Method get_scalar(): Retrieve a scalar value from the json object under the name "field_name" (with optional subfolder "subfolder_name")

Usage:

```
CppJson$get_scalar(field_name, subfolder_name = NULL)
```

Arguments:

field_name The name of the field to be accessed from json

subfolder_name (Optional) Name of the subfolder / hierarchy under which the field is stored

Returns: None

Method get_integer(): Retrieve a integer value from the json object under the name "field_name" (with optional subfolder "subfolder_name")

Usage:

```
CppJson$get_integer(field_name, subfolder_name = NULL)
```

Arguments:

field_name The name of the field to be accessed from json

subfolder_name (Optional) Name of the subfolder / hierarchy under which the field is stored

Returns: None

Method get_boolean(): Retrieve a boolean value from the json object under the name "field_name" (with optional subfolder "subfolder_name")

Usage:

```
CppJson$get_boolean(field_name, subfolder_name = NULL)
```

Arguments:

field_name The name of the field to be accessed from json

subfolder_name (Optional) Name of the subfolder / hierarchy under which the field is stored

Returns: None

Method `get_string()`: Retrieve a string value from the json object under the name "field_name" (with optional subfolder "subfolder_name")

Usage:

```
CppJson$get_string(field_name, subfolder_name = NULL)
```

Arguments:

field_name The name of the field to be accessed from json

subfolder_name (Optional) Name of the subfolder / hierarchy under which the field is stored

Returns: None

Method `get_vector()`: Retrieve a vector from the json object under the name "field_name" (with optional subfolder "subfolder_name")

Usage:

```
CppJson$get_vector(field_name, subfolder_name = NULL)
```

Arguments:

field_name The name of the field to be accessed from json

subfolder_name (Optional) Name of the subfolder / hierarchy under which the field is stored

Returns: None

Method `get_integer_vector()`: Retrieve an integer vector from the json object under the name "field_name" (with optional subfolder "subfolder_name")

Usage:

```
CppJson$get_integer_vector(field_name, subfolder_name = NULL)
```

Arguments:

field_name The name of the field to be accessed from json

subfolder_name (Optional) Name of the subfolder / hierarchy under which the field is stored

Returns: None

Method `get_string_vector()`: Retrieve a character vector from the json object under the name "field_name" (with optional subfolder "subfolder_name")

Usage:

```
CppJson$get_string_vector(field_name, subfolder_name = NULL)
```

Arguments:

field_name The name of the field to be accessed from json

subfolder_name (Optional) Name of the subfolder / hierarchy under which the field is stored

Returns: None

Method `get_numeric_list()`: Reconstruct a list of numeric vectors from the json object stored under "field_name"

Usage:

```
CppJson$get_numeric_list(field_name, key_names)
```

Arguments:

field_name The name of the field to be added to json

key_names Vector of names of list elements (each of which is a vector)

Returns: None

Method get_string_list(): Reconstruct a list of string vectors from the json object stored under "field_name"

Usage:

```
CppJson$get_string_list(field_name, key_names)
```

Arguments:

field_name The name of the field to be added to json

key_names Vector of names of list elements (each of which is a vector)

Returns: None

Method return_json_string(): Convert a JSON object to in-memory string

Usage:

```
CppJson$return_json_string()
```

Returns: JSON string

Method save_file(): Save a json object to file

Usage:

```
CppJson$save_file(filename)
```

Arguments:

filename String of filepath, must end in ".json"

Returns: None

Method load_from_file(): Load a json object from file

Usage:

```
CppJson$load_from_file(filename)
```

Arguments:

filename String of filepath, must end in ".json"

Returns: None

Method load_from_string(): Load a json object from string

Usage:

```
CppJson$load_from_string(json_string)
```

Arguments:

json_string JSON string dump

Returns: None

 CppRNG

Random Number Generator C++ Wrapper

Description

Wrapper around a C++ random number generator object (for reproducibility). The class persists a C++ random number generator throughout an R session to ensure a given seed generates the same outputs (on the same OS). If no seed is provided, the C++ random number generator is initialized using `std::random_device`.

Public fields

`rng_ptr` External pointer to a C++ `std::mt19937` class

Methods**Public methods:**

- `CppRNG$new()`

Method `new()`: Create a new CppRNG object.

Usage:

```
CppRNG$new(random_seed = -1)
```

Arguments:

`random_seed` (Optional) random seed for sampling

Returns: A new CppRNG object.

 createCppRNG

Create CppRNG Object

Description

Create an R class that wraps a C++ random number generator

Usage

```
createCppRNG(random_seed = -1)
```

Arguments

`random_seed` (Optional) random seed for sampling

Value

CppRng object

Examples

```
rng <- createCppRNG(1234)
rng <- createCppRNG()
```

createForest	<i>Create Forest Object</i>
--------------	-----------------------------

Description

Create a forest

This function is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Usage

```
createForest(  
  num_trees,  
  leaf_dimension = 1,  
  is_leaf_constant = FALSE,  
  is_exponentiated = FALSE  
)
```

Arguments

num_trees	Number of trees in the forest
leaf_dimension	Dimensionality of the outcome model
is_leaf_constant	Whether leaf is constant
is_exponentiated	Whether forest predictions should be exponentiated before being returned

Value

Forest object

Examples

```
num_trees <- 100  
leaf_dimension <- 2  
is_leaf_constant <- FALSE  
is_exponentiated <- FALSE  
forest <- createForest(num_trees, leaf_dimension, is_leaf_constant, is_exponentiated)
```

createForestDataset *Create ForestDataset Object*

Description

Create a forest dataset object

This function is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Usage

```
createForestDataset(covariates, basis = NULL, variance_weights = NULL)
```

Arguments

`covariates` Matrix of covariates
`basis` (Optional) Matrix of bases used to define a leaf regression
`variance_weights`
 (Optional) Vector of observation-specific variance weights

Value

ForestDataset object

Examples

```
covariate_matrix <- matrix(runif(10*100), ncol = 10)
basis_matrix <- matrix(rnorm(3*100), ncol = 3)
weight_vector <- rnorm(100)
forest_dataset <- createForestDataset(covariate_matrix)
forest_dataset <- createForestDataset(covariate_matrix, basis_matrix)
forest_dataset <- createForestDataset(covariate_matrix, basis_matrix, weight_vector)
```

createForestModel *Create ForestModel Object*

Description

Create a forest model object

This function is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Usage

```
createForestModel(forest_dataset, forest_model_config, global_model_config)
```

Arguments

`forest_dataset` ForestDataset object, used to initialize forest sampling data structures
`forest_model_config` ForestModelConfig object containing forest model parameters and settings
`global_model_config` GlobalModelConfig object containing global model parameters and settings

Value

ForestModel object

Examples

```
num_trees <- 100
n <- 100
p <- 10
alpha <- 0.95
beta <- 2.0
min_samples_leaf <- 2
max_depth <- 10
feature_types <- as.integer(rep(0, p))
X <- matrix(runif(n*p), ncol = p)
forest_dataset <- createForestDataset(X)
forest_model_config <- createForestModelConfig(feature_types=feature_types,
                                              num_trees=num_trees, num_features=p,
                                              num_observations=n, alpha=alpha, beta=beta,
                                              min_samples_leaf=min_samples_leaf,
                                              max_depth=max_depth, leaf_model_type=1)
global_model_config <- createGlobalModelConfig(global_error_variance=1.0)
forest_model <- createForestModel(forest_dataset, forest_model_config, global_model_config)
```

createForestModelConfig

Create ForestModelConfig Object

Description

Create a forest model config object

This function is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Usage

```

createForestModelConfig(
  feature_types = NULL,
  sweep_update_indices = NULL,
  num_trees = NULL,
  num_features = NULL,
  num_observations = NULL,
  variable_weights = NULL,
  leaf_dimension = 1,
  alpha = 0.95,
  beta = 2,
  min_samples_leaf = 5,
  max_depth = -1,
  leaf_model_type = 1,
  leaf_model_scale = NULL,
  variance_forest_shape = 1,
  variance_forest_scale = 1,
  cloglog_forest_shape = 2,
  cloglog_forest_rate = 2,
  cutpoint_grid_size = 100,
  num_features_subsample = NULL
)

```

Arguments

feature_types Vector of integer-coded feature types (integers where 0 = numeric, 1 = ordered categorical, 2 = unordered categorical)

sweep_update_indices Vector of (0-indexed) indices of trees to update in a sweep

num_trees Number of trees in the forest being sampled

num_features Number of features in training dataset

num_observations Number of observations in training dataset

variable_weights Vector specifying sampling probability for all p covariates in ForestDataset

leaf_dimension Dimension of the leaf model (default: 1)

alpha Root node split probability in tree prior (default: 0.95)

beta Depth prior penalty in tree prior (default: 2.0)

min_samples_leaf Minimum number of samples in a tree leaf (default: 5)

max_depth Maximum depth of any tree in the ensemble in the model. Setting to -1 does not enforce any depth limits on trees. Default: -1.

leaf_model_type Integer specifying the leaf model type (0 = constant leaf, 1 = univariate leaf regression, 2 = multivariate leaf regression). Default: 0.

`leaf_model_scale`
Scale parameter used in Gaussian leaf models (can either be a scalar or a $q \times q$ matrix, where q is the dimensionality of the basis and is only >1 when `leaf_model_int = 2`). Calibrated internally as $1/\text{num_trees}$, propagated along diagonal if needed for multivariate leaf models.

`variance_forest_shape`
Shape parameter for IG leaf models (applicable when `leaf_model_type = 3`).
Default: 1.

`variance_forest_scale`
Scale parameter for IG leaf models (applicable when `leaf_model_type = 3`).
Default: 1.

`cloglog_forest_shape`
Shape parameter for conditional gamma component of cloglog leaf models (applicable when `leaf_model_type = 4`). Default: 1.

`cloglog_forest_rate`
Rate parameter for conditional gamma component of cloglog leaf models (applicable when `leaf_model_type = 4`). Default: 1.

`cutpoint_grid_size`
Number of unique cutpoints to consider (default: 100)

`num_features_subsample`
Number of features to subsample for the GFR algorithm

Value

ForestModelConfig object

Examples

```
config <- createForestModelConfig(num_trees = 10, num_features = 5, num_observations = 100)
```

```
createForestSamples    Create ForestSamples Object
```

Description

Create a container of forest samples

This function is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the `stochtree`'s advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Usage

```
createForestSamples(  
  num_trees,  
  leaf_dimension = 1,  
  is_leaf_constant = FALSE,  
  is_exponentiated = FALSE  
)
```

Arguments

num_trees	Number of trees
leaf_dimension	Dimensionality of the outcome model
is_leaf_constant	
	Whether leaf is constant
is_exponentiated	
	Whether forest predictions should be exponentiated before being returned

Value

ForestSamples object

Examples

```
num_trees <- 100
leaf_dimension <- 2
is_leaf_constant <- FALSE
is_exponentiated <- FALSE
forest_samples <- createForestSamples(num_trees, leaf_dimension, is_leaf_constant, is_exponentiated)
```

```
createGlobalModelConfig
```

Create GlobalModelConfig Object

Description

Create a global model config object

This function is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Usage

```
createGlobalModelConfig(global_error_variance = 1)
```

Arguments

global_error_variance	
	Global error variance parameter (default: 1.0)

Value

GlobalModelConfig object

Examples

```
config <- createGlobalModelConfig(global_error_variance = 100)
```

createOutcome *Create Outcome Object*

Description

Create an outcome object

This function is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Usage

```
createOutcome(outcome)
```

Arguments

outcome Vector of outcome values

Value

Outcome object

Examples

```
X <- matrix(runif(10*100), ncol = 10)
y <- -5 + 10*(X[,1] > 0.5) + rnorm(100)
outcome <- createOutcome(y)
```

createRandomEffectSamples
Create RandomEffectSamples Object

Description

Create a RandomEffectSamples object

This function is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Usage

```
createRandomEffectSamples(num_components, num_groups, random_effects_tracker)
```

Arguments

num_components Number of "components" or bases defining the random effects regression
 num_groups Number of random effects groups
 random_effects_tracker
 Object of type RandomEffectsTracker

Value

RandomEffectSamples object

Examples

```
n <- 100
rfx_group_ids <- sample(1:2, size = n, replace = TRUE)
rfx_basis <- matrix(rep(1.0, n), ncol=1)
num_groups <- length(unique(rfx_group_ids))
num_components <- ncol(rfx_basis)
rfx_tracker <- createRandomEffectsTracker(rfx_group_ids)
rfx_samples <- createRandomEffectSamples(num_components, num_groups, rfx_tracker)
```

createRandomEffectsDataset

Create RandomEffectsDataset Object

Description

Create a random effects dataset object

This function is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Usage

```
createRandomEffectsDataset(group_labels, basis, variance_weights = NULL)
```

Arguments

group_labels Vector of group labels
 basis Matrix of bases used to define the random effects regression (for an intercept-only model, pass an array of ones)
 variance_weights
 (Optional) Vector of observation-specific variance weights

Value

RandomEffectsDataset object

Examples

```
rfx_group_ids <- sample(1:2, size = 100, replace = TRUE)
rfx_basis <- matrix(rnorm(3*100), ncol = 3)
weight_vector <- rnorm(100)
rfx_dataset <- createRandomEffectsDataset(rfx_group_ids, rfx_basis)
rfx_dataset <- createRandomEffectsDataset(rfx_group_ids, rfx_basis, weight_vector)
```

createRandomEffectsModel

Create RandomEffectsModel Object

Description

Create a RandomEffectsModel object

This function is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Usage

```
createRandomEffectsModel(num_components, num_groups)
```

Arguments

num_components Number of "components" or bases defining the random effects regression

num_groups Number of random effects groups

Value

RandomEffectsModel object

Examples

```
n <- 100
rfx_group_ids <- sample(1:2, size = n, replace = TRUE)
rfx_basis <- matrix(rep(1.0, n), ncol=1)
num_groups <- length(unique(rfx_group_ids))
num_components <- ncol(rfx_basis)
rfx_model <- createRandomEffectsModel(num_components, num_groups)
```

`createRandomEffectsTracker`*Create RandomEffectsTracker Object*

Description

Create a RandomEffectsTracker object

This function is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Usage

```
createRandomEffectsTracker(rfx_group_indices)
```

Arguments

`rfx_group_indices`

Integer indices indicating groups used to define random effects

Value

RandomEffectsTracker object

Examples

```
n <- 100
rfx_group_ids <- sample(1:2, size = n, replace = TRUE)
rfx_basis <- matrix(rep(1.0, n), ncol=1)
num_groups <- length(unique(rfx_group_ids))
num_components <- ncol(rfx_basis)
rfx_tracker <- createRandomEffectsTracker(rfx_group_ids)
```

`DataPreprocessing`*Data Preprocessing Routines*

Description

The functions in this group are designed to handle data preprocessing for stochastic forest models. For example, factor-valued columns in data frames are either one-hot encoded or converted to integer indices before the dataframe is converted to a standard matrix format for sampling. This preprocessing routine defines a set of "steps" that must be repeated on out-of-sample datasets before predictions can be obtained from a sampling model.

`preprocessTrainData` preprocesses covariates for the forest sampler routines, depending on the input type. DataFrames will be preprocessed based on their column types (numeric columns are not

modified, ordered factors are integer coded, and unordered factors are one-hot encoded). Matrices are unmodified (assuming all columns are numeric). This function also records and returns a "metadata" list with preprocessing details to ensure that other datasets can be preprocessing identically.

`preprocessPredictionData` preprocesses covariates for the forest sampler routines, based on the steps outlined in a metadata list produced by `preprocessTrainData`.

These procedures are handled internally in the `bart()` and `bcf()` functions, but they are provided in `stochtree` as convenience functions for users writing custom samplers. Furthermore, while R lists can be serialized to RDS format, we offer a number of JSON serialization routines for the metadata list produced by `preprocessTrainData` for consistency with the broader serialization approach of `stochtree` (see [BARTSerialization](#) and [BCFSerialization](#)).

Following the API for serializing `bartmodel` and `bcfmodel` objects, we can convert metadata to JSON or JSON strings via `savePreprocessorToJson` and `savePreprocessorToJsonString`. Similarly, we can reload a metadata list from JSON or JSON strings via `createPreprocessorFromJson` and `createPreprocessorFromJsonString`.

Usage

```
preprocessTrainData(input_data)

preprocessPredictionData(input_data, metadata)

savePreprocessorToJson(object)

savePreprocessorToJsonString(object)

createPreprocessorFromJson(json_object)

createPreprocessorFromJsonString(json_string)
```

Arguments

<code>input_data</code>	Covariates, provided as either a dataframe or a matrix
<code>metadata</code>	List containing information on variables, including train set categories for categorical variables
<code>object</code>	List containing information on variables, including train set categories for categorical variables
<code>json_object</code>	in-memory wrapper around JSON C++ object containing covariate preprocessor metadata
<code>json_string</code>	in-memory JSON string containing covariate preprocessor metadata

Value

`preprocessTrainData` returns a list with transformed matrix data and a "metadata" list with details on the preprocessing procedures applied. `preprocessPredictionData` returns a matrix reflecting the data transformations specified in the provided metadata list.

`savePreprocessorToJson` return an object of type `CppJson`. `savePreprocessorToJsonString` returns a string dump of the preprocessor's JSON representation.

createPreprocessorFromJson and createPreprocessorFromJsonString both return metadata lists.

Examples

```
# Check that running the same data through `preprocessTrainData`
# and `preprocessPredictionData` yields the same result
n <- 100
x1 <- rnorm(n)
x2 <- factor(sample(1:3, n, replace = TRUE), ordered = TRUE)
x3 <- factor(sample(1:3, n, replace = TRUE), ordered = FALSE)
df1 <- data.frame(x1 = x1, x2 = x2, x3 = x3)
df2 <- data.frame(x1 = x1, x2 = x2, x3 = x3)
preprocess_train_list <- preprocessTrainData(df1)
df1_process <- preprocess_train_list$data
df1_metadata <- preprocess_train_list$metadata
df2_process <- preprocessPredictionData(df2, df1_metadata)
all.equal(df1_process, df2_process)

# Save to in-memory JSON
metadata_json <- savePreprocessorToJson(df1_metadata)
# Save to JSON string
metadata_json_string <- savePreprocessorToJsonString(df1_metadata)

# Reload metadata list from in-memory JSON object
metadata_roundtrip <- createPreprocessorFromJson(metadata_json)
# Reload metadata list from JSON string
metadata_roundtrip <- createPreprocessorFromJsonString(metadata_json_string)

cov_df <- data.frame(x1 = 1:5, x2 = 5:1, x3 = 6:10)
metadata <- list(num_ordered_cat_vars = 0, num_unordered_cat_vars = 0,
               num_numeric_vars = 3, numeric_vars = c("x1", "x2", "x3"))
X_preprocessed <- preprocessPredictionData(cov_df, metadata)
```

extractParameter *Extract Parameter Samples Generic Function*

Description

Generic function for extracting parameter samples from a model object (BCF, BART, etc...)

Usage

```
extractParameter(object, term)
```

Arguments

object	Fitted model object from which to extract parameter samples
term	Name of the parameter to extract (e.g., "sigma2", "y_hat_train", etc.)

Value

Parameter sample array

Examples

```
n <- 100
p <- 10
X <- matrix(runif(n*p), ncol = p)
rfx_group_ids <- sample(1:2, size = n, replace = TRUE)
rfx_basis <- rep(1.0, n)
y <- (-5 + 10*(X[,1] > 0.5)) + (-2*(rfx_group_ids==1)+2*(rfx_group_ids==2)) + rnorm(n)
bart_model <- bart(X_train=X, y_train=y, rfx_group_ids_train=rfx_group_ids,
                  rfx_basis_train = rfx_basis, num_gfr=0, num_mcmc=10)
sigma2_samples <- extractParameter(bart_model, "sigma2")
```

extractParameter.bartmodel

Extract BART Parameter Samples

Description

Extract a vector, matrix or array of parameter samples from a BART model by name. Random effects are handled by a separate getRandomEffectSamples function due to the complexity of the random effects parameters. If the requested model term is not found, an error is thrown. The following conventions are used for parameter names:

- Global error variance: "sigma2", "global_error_scale", "sigma2_global"
- Leaf scale: "sigma2_leaf", "leaf_scale"
- In-sample mean function predictions: "y_hat_train"
- Test set mean function predictions: "y_hat_test"
- In-sample variance forest predictions: "sigma2_x_train", "var_x_train"
- Test set variance forest predictions: "sigma2_x_test", "var_x_test"
- Ordinal model cutpoints (valid only for ordinal cloglog models): "cloglog_cutpoints", "cutpoints"

Usage

```
## S3 method for class 'bartmodel'
extractParameter(object, term)
```

Arguments

object	Object of type bartmodel containing draws of a BART model and associated sampling outputs.
term	Name of the parameter to extract (e.g., "sigma2", "y_hat_train", etc.)

Value

Array of parameter samples. If the underlying parameter is a scalar, this will be a vector of length `num_samples`. If the underlying parameter is vector-valued, this will be `(parameter_dimension x num_samples)` matrix, and if the underlying parameter is multidimensional, this will be an array of dimension `(parameter_dimension_1 x parameter_dimension_2 x ... x num_samples)`.

Examples

```
n <- 100
p <- 5
X <- matrix(runif(n*p), ncol = p)
f_XW <- (
  ((0 <= X[,1]) & (0.25 > X[,1])) * (-7.5) +
  ((0.25 <= X[,1]) & (0.5 > X[,1])) * (-2.5) +
  ((0.5 <= X[,1]) & (0.75 > X[,1])) * (2.5) +
  ((0.75 <= X[,1]) & (1 > X[,1])) * (7.5)
)
snr <- 3
group_ids <- rep(c(1,2), n %/% 2)
rfx_coefs <- matrix(c(-1, -1, 1, 1), nrow=2, byrow=TRUE)
rfx_basis <- cbind(1, runif(n, -1, 1))
rfx_term <- rowSums(rfx_coefs[group_ids,] * rfx_basis)
E_y <- f_XW + rfx_term
y <- E_y + rnorm(n, 0, 1)*(sd(E_y)/snr)
test_set_pct <- 0.2
n_test <- round(test_set_pct*n)
n_train <- n - n_test
test_inds <- sort(sample(1:n, n_test, replace = FALSE))
train_inds <- (1:n)[!((1:n) %in% test_inds)]
X_test <- X[test_inds,]
X_train <- X[train_inds,]
y_test <- y[test_inds]
y_train <- y[train_inds]
rfx_group_ids_test <- group_ids[test_inds]
rfx_group_ids_train <- group_ids[train_inds]
rfx_basis_test <- rfx_basis[test_inds,]
rfx_basis_train <- rfx_basis[train_inds,]
rfx_term_test <- rfx_term[test_inds]
rfx_term_train <- rfx_term[train_inds]
bart_model <- bart(X_train = X_train, y_train = y_train, X_test = X_test,
  rfx_group_ids_train = rfx_group_ids_train,
  rfx_group_ids_test = rfx_group_ids_test,
  rfx_basis_train = rfx_basis_train,
  rfx_basis_test = rfx_basis_test,
  num_gfr = 10, num_burnin = 0, num_mcmc = 10)
sigma2_samples <- extractParameter(bart_model, "sigma2")
```

extractParameter.bcfmodel

Extract BCF Parameter Samples

Description

Extract a vector, matrix or array of parameter samples from a BCF model by name. Random effects are handled by a separate `getRandomEffectSamples` function due to the complexity of the random effects parameters. If the requested model term is not found, an error is thrown. The following conventions are used for parameter names:

- Global error variance: "sigma2", "global_error_scale", "sigma2_global"
- Prognostic forest leaf scale: "sigma2_leaf_mu", "leaf_scale_mu", "mu_leaf_scale"
- Treatment effect forest leaf scale: "sigma2_leaf_tau", "leaf_scale_tau", "tau_leaf_scale"
- Adaptive coding parameters: "adaptive_coding" (returns both the control and treated parameters jointly, with control in the first row and treated in the second row)
- In-sample mean function predictions: "y_hat_train"
- Test set mean function predictions: "y_hat_test"
- In-sample treatment effect forest predictions: "tau_hat_train"
- Test set treatment effect forest predictions: "tau_hat_test"
- Treatment effect intercept: "tau_0", "treatment_intercept", "tau_intercept"
- In-sample variance forest predictions: "sigma2_x_train", "var_x_train"
- Test set variance forest predictions: "sigma2_x_test", "var_x_test"

Usage

```
## S3 method for class 'bcfmodel'
extractParameter(object, term)
```

Arguments

object	Object of type <code>bcfmodel</code> containing draws of a BCF model and associated sampling outputs.
term	Name of the parameter to extract (e.g., "sigma2", "y_hat_train", etc.)

Value

Array of parameter samples. If the underlying parameter is a scalar, this will be a vector of length `num_samples`. If the underlying parameter is vector-valued, this will be (`parameter_dimension` x `num_samples`) matrix, and if the underlying parameter is multidimensional, this will be an array of dimension (`parameter_dimension_1` x `parameter_dimension_2` x ... x `num_samples`).

Examples

```
n <- 500
p <- 5
X <- matrix(runif(n*p), ncol = p)
mu_x <- (
  ((0 <= X[,1]) & (0.25 > X[,1])) * (-7.5) +
  ((0.25 <= X[,1]) & (0.5 > X[,1])) * (-2.5) +
  ((0.5 <= X[,1]) & (0.75 > X[,1])) * (2.5) +
```

```

      ((0.75 <= X[,1]) & (1 > X[,1])) * (7.5)
    )
    pi_x <- (
      ((0 <= X[,1]) & (0.25 > X[,1])) * (0.2) +
      ((0.25 <= X[,1]) & (0.5 > X[,1])) * (0.4) +
      ((0.5 <= X[,1]) & (0.75 > X[,1])) * (0.6) +
      ((0.75 <= X[,1]) & (1 > X[,1])) * (0.8)
    )
    tau_x <- (
      ((0 <= X[,2]) & (0.25 > X[,2])) * (0.5) +
      ((0.25 <= X[,2]) & (0.5 > X[,2])) * (1.0) +
      ((0.5 <= X[,2]) & (0.75 > X[,2])) * (1.5) +
      ((0.75 <= X[,2]) & (1 > X[,2])) * (2.0)
    )
    Z <- rbinom(n, 1, pi_x)
    E_XZ <- mu_x + Z*tau_x
    snr <- 3
    rfx_group_ids <- rep(c(1,2), n %/% 2)
    rfx_coefs <- matrix(c(-1, -1, 1, 1), nrow=2, byrow=TRUE)
    rfx_basis <- cbind(1, runif(n, -1, 1))
    rfx_term <- rowSums(rfx_coefs[rfx_group_ids,] * rfx_basis)
    y <- E_XZ + rfx_term + rnorm(n, 0, 1)*(sd(E_XZ)/snr)
    bcf_model <- bcf(X_train = X, y_train = y, Z_train = Z,
      rfx_group_ids_train = rfx_group_ids,
      rfx_basis_train = rfx_basis,
      num_gfr = 10, num_burnin = 0, num_mcmc = 10)
    sigma2_samples <- extractParameter(bcf_model, "sigma2")

```

Forest

Forest C++ Wrapper

Description

Wrapper around a C++ class that stores a single ensemble of decision trees (often treated as the "active forest" / current state of a forest term in a sampling loop in R)

This class is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Public fields

`forest_ptr` External pointer to a C++ `TreeEnsemble` class

`internal_forest_is_empty` Whether the forest has not yet been "initialized" such that its predict function can be called.

Methods**Public methods:**

- `Forest$new()`
- `Forest$merge_forest()`
- `Forest$add_constant()`
- `Forest$multiply_constant()`
- `Forest$predict()`
- `Forest$predict_raw()`
- `Forest$set_root_leaves()`
- `Forest$prepare_for_sampler()`
- `Forest$adjust_residual()`
- `Forest$num_trees()`
- `Forest$leaf_dimension()`
- `Forest$is_leaf_constant()`
- `Forest$is_exponentiated()`
- `Forest$add_numeric_split_tree()`
- `Forest$get_tree_leaves()`
- `Forest$get_tree_split_counts()`
- `Forest$get_forest_split_counts()`
- `Forest$tree_max_depth()`
- `Forest$average_max_depth()`
- `Forest$is_empty()`

Method `new()`: Create a new Forest object.

Usage:

```
Forest$new(  
  num_trees,  
  leaf_dimension = 1,  
  is_leaf_constant = FALSE,  
  is_exponentiated = FALSE  
)
```

Arguments:

`num_trees` Number of trees in the forest

`leaf_dimension` Dimensionality of the outcome model

`is_leaf_constant` Whether leaf is constant

`is_exponentiated` Whether forest predictions should be exponentiated before being returned

Returns: A new Forest object.

Method `merge_forest()`: Create a larger forest by merging the trees of this forest with those of another forest

Usage:

```
Forest$merge_forest(forest)
```

Arguments:

forest Forest to be merged into this forest

Method `add_constant()`: Add a constant value to every leaf of every tree in an ensemble. If leaves are multi-dimensional, `constant_value` will be added to every dimension of the leaves.

Usage:

```
Forest$add_constant(constant_value)
```

Arguments:

`constant_value` Value that will be added to every leaf of every tree

Method `multiply_constant()`: Multiply every leaf of every tree by a constant value. If leaves are multi-dimensional, `constant_multiple` will be multiplied through every dimension of the leaves.

Usage:

```
Forest$multiply_constant(constant_multiple)
```

Arguments:

`constant_multiple` Value that will be multiplied by every leaf of every tree

Method `predict()`: Predict forest on every sample in `forest_dataset`

Usage:

```
Forest$predict(forest_dataset)
```

Arguments:

`forest_dataset` ForestDataset R class

Returns: vector of predictions with as many rows as in `forest_dataset`

Method `predict_raw()`: Predict "raw" leaf values (without being multiplied by basis) for every sample in `forest_dataset`

Usage:

```
Forest$predict_raw(forest_dataset)
```

Arguments:

`forest_dataset` ForestDataset R class

Returns: Array of predictions for each observation in `forest_dataset` and each sample in the ForestSamples class with each prediction having the dimensionality of the forests' leaf model. In the case of a constant leaf model or univariate leaf regression, this array is a vector (length is the number of observations). In the case of a multivariate leaf regression, this array is a matrix (number of observations by leaf model dimension, number of samples).

Method `set_root_leaves()`: Set a constant predicted value for every tree in the ensemble. Stops program if any tree is more than a root node.

Usage:

```
Forest$set_root_leaves(leaf_value)
```

Arguments:

`leaf_value` Constant leaf value(s) to be fixed for each tree in the ensemble indexed by `forest_num`. Can be either a single number or a vector, depending on the forest's leaf dimension.

Method `prepare_for_sampler()`: Set a constant predicted value for every tree in the ensemble. Stops program if any tree is more than a root node.

Usage:

```
Forest$prepare_for_sampler(
  dataset,
  outcome,
  forest_model,
  leaf_model_int,
  leaf_value
)
```

Arguments:

`dataset` ForestDataset Dataset class (covariates, basis, etc...)

`outcome` Outcome Outcome class (residual / partial residual)

`forest_model` ForestModel object storing tracking structures used in training / sampling

`leaf_model_int` Integer value encoding the leaf model type (0 = constant gaussian, 1 = univariate gaussian, 2 = multivariate gaussian, 3 = log linear variance).

`leaf_value` Constant leaf value(s) to be fixed for each tree in the ensemble indexed by `forest_num`. Can be either a single number or a vector, depending on the forest's leaf dimension.

Method `adjust_residual()`: Adjusts residual based on the predictions of a forest

This is typically run just once at the beginning of a forest sampling algorithm. After trees are initialized with constant root node predictions, their root predictions are subtracted out of the residual.

Usage:

```
Forest$adjust_residual(dataset, outcome, forest_model, requires_basis, add)
```

Arguments:

`dataset` ForestDataset object storing the covariates and bases for a given forest

`outcome` Outcome object storing the residuals to be updated based on forest predictions

`forest_model` ForestModel object storing tracking structures used in training / sampling

`requires_basis` Whether or not a forest requires a basis for prediction

`add` Whether forest predictions should be added to or subtracted from residuals

Method `num_trees()`: Return number of trees in each ensemble of a Forest object

Usage:

```
Forest$num_trees()
```

Returns: Tree count

Method `leaf_dimension()`: Return output dimension of trees in a Forest object

Usage:

```
Forest$leaf_dimension()
```

Returns: Leaf node parameter size

Method `is_leaf_constant()`: Return constant leaf status of trees in a Forest object

Usage:

`Forest$is_leaf_constant()`

Returns: TRUE if leaves are constant, FALSE otherwise

Method `is_exponentiated()`: Return exponentiation status of trees in a Forest object

Usage:

`Forest$is_exponentiated()`

Returns: TRUE if leaf predictions must be exponentiated, FALSE otherwise

Method `add_numeric_split_tree()`: Add a numeric (i.e. $X[,i] \leq c$) split to a given tree in the ensemble

Usage:

```
Forest$add_numeric_split_tree(
  tree_num,
  leaf_num,
  feature_num,
  split_threshold,
  left_leaf_value,
  right_leaf_value
)
```

Arguments:

`tree_num` Index of the tree to be split

`leaf_num` Leaf to be split

`feature_num` Feature that defines the new split

`split_threshold` Value that defines the cutoff of the new split

`left_leaf_value` Value (or vector of values) to assign to the newly created left node

`right_leaf_value` Value (or vector of values) to assign to the newly created right node

Method `get_tree_leaves()`: Retrieve a vector of indices of leaf nodes for a given tree in a given forest

Usage:

`Forest$get_tree_leaves(tree_num)`

Arguments:

`tree_num` Index of the tree for which leaf indices will be retrieved

Method `get_tree_split_counts()`: Retrieve a vector of split counts for every training set variable in a given tree in the forest

Usage:

`Forest$get_tree_split_counts(tree_num, num_features)`

Arguments:

`tree_num` Index of the tree for which split counts will be retrieved

`num_features` Total number of features in the training set

Method `get_forest_split_counts()`: Retrieve a vector of split counts for every training set variable in the forest

Usage:

```
Forest$get_forest_split_counts(num_features)
```

Arguments:

num_features Total number of features in the training set

Method `tree_max_depth()`: Maximum depth of a specific tree in the forest

Usage:

```
Forest$tree_max_depth(tree_num)
```

Arguments:

tree_num Tree index within forest

Returns: Maximum leaf depth

Method `average_max_depth()`: Average the maximum depth of each tree in the forest

Usage:

```
Forest$average_max_depth()
```

Returns: Average maximum depth

Method `is_empty()`: When a forest object is created, it is "empty" in the sense that none of its component trees have leaves with values. There are two ways to "initialize" a Forest object. First, the `set_root_leaves()` method simply initializes every tree in the forest to a single node carrying the same (user-specified) leaf value. Second, the `prepare_for_sampler()` method initializes every tree in the forest to a single node with the same value and also propagates this information through to a ForestModel object, which must be synchronized with a Forest during a forest sampler loop.

Usage:

```
Forest$is_empty()
```

Returns: TRUE if a Forest has not yet been initialized with a constant root value, FALSE otherwise if the forest has already been initialized / grown.

ForestDataset

Forest Dataset C++ Wrapper

Description

Wrapper around a C++ dataset class used to sample a forest. A dataset consists of three matrices / vectors: covariates, bases, and variance weights. Both the basis vector and variance weights are optional.

This class is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Public fields

data_ptr External pointer to a C++ ForestDataset class

Methods**Public methods:**

- `ForestDataset$new()`
- `ForestDataset$update_basis()`
- `ForestDataset$update_variance_weights()`
- `ForestDataset$num_observations()`
- `ForestDataset$num_covariates()`
- `ForestDataset$num_basis()`
- `ForestDataset$get_covariates()`
- `ForestDataset$get_basis()`
- `ForestDataset$get_variance_weights()`
- `ForestDataset$has_basis()`
- `ForestDataset$has_variance_weights()`
- `ForestDataset$has_auxiliary_dimension()`
- `ForestDataset$add_auxiliary_dimension()`
- `ForestDataset$get_auxiliary_data_value()`
- `ForestDataset$set_auxiliary_data_value()`
- `ForestDataset$get_auxiliary_data_vector()`

Method `new()`: Create a new ForestDataset object.

Usage:

```
ForestDataset$new(covariates, basis = NULL, variance_weights = NULL)
```

Arguments:

covariates Matrix of covariates

basis (Optional) Matrix of bases used to define a leaf regression

variance_weights (Optional) Vector of observation-specific variance weights

Returns: A new ForestDataset object.

Method `update_basis()`: Update basis matrix in a dataset

Usage:

```
ForestDataset$update_basis(basis)
```

Arguments:

basis Updated matrix of bases used to define a leaf regression

Method `update_variance_weights()`: Update variance_weights in a dataset

Usage:

```
ForestDataset$update_variance_weights(variance_weights, exponentiate = F)
```

Arguments:

`variance_weights` Updated vector of variance weights used to define individual variance / case weights

`exponentiate` Whether or not input vector should be exponentiated before being written to the Dataset's variance weights. Default: F.

Method `num_observations()`: Return number of observations in a ForestDataset object

Usage:

```
ForestDataset$num_observations()
```

Returns: Observation count

Method `num_covariates()`: Return number of covariates in a ForestDataset object

Usage:

```
ForestDataset$num_covariates()
```

Returns: Covariate count

Method `num_basis()`: Return number of bases in a ForestDataset object

Usage:

```
ForestDataset$num_basis()
```

Returns: Basis count

Method `get_covariates()`: Return covariates as an R matrix

Usage:

```
ForestDataset$get_covariates()
```

Returns: Covariate data

Method `get_basis()`: Return bases as an R matrix

Usage:

```
ForestDataset$get_basis()
```

Returns: Basis data

Method `get_variance_weights()`: Return variance weights as an R vector

Usage:

```
ForestDataset$get_variance_weights()
```

Returns: Variance weight data

Method `has_basis()`: Whether or not a dataset has a basis matrix

Usage:

```
ForestDataset$has_basis()
```

Returns: True if basis matrix is loaded, false otherwise

Method `has_variance_weights()`: Whether or not a dataset has variance weights

Usage:

```
ForestDataset$has_variance_weights()
```

Returns: True if variance weights are loaded, false otherwise

Method `has_auxiliary_dimension()`: Whether or not a dataset has auxiliary data stored at the dimension indicated

Usage:

```
ForestDataset$has_auxiliary_dimension(dim_idx)
```

Arguments:

`dim_idx` Dimension of auxiliary data

Returns: True if auxiliary data has been allocated for `dim_idx` False otherwise

Method `add_auxiliary_dimension()`: Initialize a new dimension / lane of auxiliary data and allocate data in its place

Usage:

```
ForestDataset$add_auxiliary_dimension(dim_size)
```

Arguments:

`dim_size` Size of the new vector of data to allocate

Returns: None

Method `get_auxiliary_data_value()`: Retrieve auxiliary data value

Usage:

```
ForestDataset$get_auxiliary_data_value(dim_idx, element_idx)
```

Arguments:

`dim_idx` Dimension from which data value to be retrieved

`element_idx` Element to retrieve from dimension `dim_idx`

Returns: Floating point value stored in the requested auxiliary data space

Method `set_auxiliary_data_value()`: Set auxiliary data value

Usage:

```
ForestDataset$set_auxiliary_data_value(dim_idx, element_idx, value)
```

Arguments:

`dim_idx` Dimension in which data value to be set

`element_idx` Element to set within dimension `dim_idx`

`value` Data value to set at auxiliary data dimension `dim_idx` and element `element_idx`

Returns: None

Method `get_auxiliary_data_vector()`: Retrieve entire auxiliary data vector

Usage:

```
ForestDataset$get_auxiliary_data_vector(dim_idx)
```

Arguments:

`dim_idx` Dimension to retrieve

Returns: Vector of all of the auxiliary data stored at dimension `dim_idx`

ForestKernelComputation

Forest Kernel Computation Routines

Description

Decision tree ensembles can be represented in part by a "kernel" function whose distance metric is based on the extent to which two observations are mapped to the same leaf nodes. This function group offers utilities for evaluating this kernel.

`computeForestLeafIndices` computes and return a vector representation of a forest's leaf predictions for every observation in a dataset. The resulting vector has a "row-major" format that can be easily re-represented as a CSR sparse matrix: elements are organized so that the first n elements correspond to leaf predictions for all n observations in a dataset for the first tree in an ensemble, the next n elements correspond to predictions for the second tree and so on. The "data" for each element corresponds to a uniquely mapped column index that corresponds to a single leaf of a single tree (i.e. if tree 1 has 3 leaves, its column indices range from 0 to 2, and then tree 2's leaf indices begin at 3, etc...).

`computeForestLeafVariances` returns each forest's leaf node scale parameters. If leaf scale is not sampled for the forest in question, the function throws an error that the leaf model does not have a stochastic scale parameter.

`computeForestMaxLeafIndex` computes and returns the largest possible leaf index computable by `computeForestLeafIndices` for the forests in a designated forest sample container.

These functions are intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the `stochtree`'s advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Usage

```
computeForestLeafIndices(
  model_object,
  covariates,
  forest_type = NULL,
  propensity = NULL,
  forest_inds = NULL
)

computeForestLeafVariances(model_object, forest_type, forest_inds = NULL)

computeForestMaxLeafIndex(model_object, forest_type = NULL, forest_inds = NULL)
```

Arguments

`model_object` Object of type `bartmodel`, `bcfmodel`, or `ForestSamples` corresponding to a BART / BCF model with at least one forest sample, or a low-level `ForestSamples` object.

covariates	Covariates to use for prediction. Must have the same dimensions / column types as the data used to train a forest.
forest_type	Which forest to use from model_object. Valid inputs depend on the model type, and whether or not a <ol style="list-style-type: none"> 1. BART <ul style="list-style-type: none"> • 'mean': Extracts leaf indices for the mean forest • 'variance': Extracts leaf indices for the variance forest 2. BCF <ul style="list-style-type: none"> • 'prognostic': Extracts leaf indices for the prognostic forest • 'treatment': Extracts leaf indices for the treatment effect forest • 'variance': Extracts leaf indices for the variance forest 3. ForestSamples <ul style="list-style-type: none"> • NULL: It is not necessary to disambiguate when this function is called directly on a ForestSamples object. This is the default value of this
propensity	(Optional) Propensities used for prediction (BCF-only).
forest_inds	(Optional) Indices of the forest sample(s) for which to compute max leaf indices. If not provided, this function will return max leaf indices for every sample of a forest. This function uses 0-indexing, so the first forest sample corresponds to forest_num = 0, and so on.

Value

computeForestLeafIndices returns a vector of size num_obs * num_trees, where num_obs = nrow(covariates) and num_trees is the number of trees in the relevant forest of model_object.

computeForestLeafVariances returns a vector of size length(forest_inds) with the leaf scale parameter for each requested forest.

computeForestMaxLeafIndex returns a vector containing the largest possible leaf index computable by computeForestLeafIndices for the forests in a designated forest sample container.

Examples

```
X <- matrix(runif(10*100), ncol = 10)
y <- -5 + 10*(X[,1] > 0.5) + rnorm(100)
bart_model <- bart(X, y, num_gfr=0, num_mcmc=10)
leaf_indices <- computeForestLeafIndices(bart_model, X, "mean")
leaf_indices <- computeForestLeafIndices(bart_model, X, "mean", 0)
leaf_indices <- computeForestLeafIndices(bart_model, X, "mean", c(1,3,9))
leaf_variances <- computeForestLeafVariances(bart_model, "mean")
leaf_variances <- computeForestLeafVariances(bart_model, "mean", 0)
leaf_variances <- computeForestLeafVariances(bart_model, "mean", c(1,3,5))
max_leaf_index <- computeForestMaxLeafIndex(bart_model, "mean")
max_leaf_index <- computeForestMaxLeafIndex(bart_model, "mean", 0)
max_leaf_index <- computeForestMaxLeafIndex(bart_model, "mean", c(1,3,9))
```

ForestModel

Forest Model C++ Wrapper

Description

Wraps the C++ data structures needed to sample an ensemble of decision trees and exposes functionality to run a forest sampler (using either MCMC or the grow-from-root algorithm).

This class is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Public fields

tracker_ptr External pointer to a C++ ForestTracker class

tree_prior_ptr External pointer to a C++ TreePrior class

Methods

Public methods:

- `ForestModel$new()`
- `ForestModel$sample_one_iteration()`
- `ForestModel$get_cached_forest_predictions()`
- `ForestModel$propagate_basis_update()`
- `ForestModel$propagate_residual_update()`
- `ForestModel$update_alpha()`
- `ForestModel$update_beta()`
- `ForestModel$update_min_samples_leaf()`
- `ForestModel$update_max_depth()`
- `ForestModel$get_alpha()`
- `ForestModel$get_beta()`
- `ForestModel$get_min_samples_leaf()`
- `ForestModel$get_max_depth()`

Method `new()`: Create a new ForestModel object.

Usage:

```
ForestModel$new(  
  forest_dataset,  
  feature_types,  
  num_trees,  
  n,  
  alpha,  
  beta,  
  min_samples_leaf,  
  max_depth = -1  
)
```

Arguments:

forest_dataset ForestDataset object, used to initialize forest sampling data structures
 feature_types Feature types (integers where 0 = numeric, 1 = ordered categorical, 2 = un-ordered categorical)
 num_trees Number of trees in the forest being sampled
 n Number of observations in forest_dataset
 alpha Root node split probability in tree prior
 beta Depth prior penalty in tree prior
 min_samples_leaf Minimum number of samples in a tree leaf
 max_depth Maximum depth that any tree can reach

Returns: A new ForestModel object.

Method `sample_one_iteration()`: Run a single iteration of the forest sampling algorithm (MCMC or GFR)

Usage:

```

ForestModel$sample_one_iteration(
  forest_dataset,
  residual,
  forest_samples,
  active_forest,
  rng,
  forest_model_config,
  global_model_config,
  num_threads = -1,
  keep_forest = TRUE,
  gfr = TRUE
)

```

Arguments:

forest_dataset Dataset used to sample the forest
 residual Outcome used to sample the forest
 forest_samples Container of forest samples
 active_forest "Active" forest updated by the sampler in each iteration
 rng Wrapper around C++ random number generator
 forest_model_config ForestModelConfig object containing forest model parameters and settings
 global_model_config GlobalModelConfig object containing global model parameters and settings
 num_threads Number of threads to use in the GFR and MCMC algorithms, as well as prediction. If OpenMP is not available on a user's system, this will default to 1, otherwise to the maximum number of available threads.
 keep_forest (Optional) Whether the updated forest sample should be saved to forest_samples. Default: TRUE.
 gfr (Optional) Whether or not the forest should be sampled using the "grow-from-root" (GFR) algorithm. Default: TRUE.

Method `get_cached_forest_predictions()`: Extract an internally-cached prediction of a forest on the training dataset in a sampler.

Usage:

```
ForestModel$get_cached_forest_predictions()
```

Returns: Vector with as many elements as observations in the training dataset

Method `propagate_basis_update()`: Propagates basis update through to the (full/partial) residual by iteratively (a) adding back in the previous prediction of each tree, (b) recomputing predictions for each tree (caching on the C++ side), (c) subtracting the new predictions from the residual.

This is useful in cases where a basis (for e.g. leaf regression) is updated outside of a tree sampler (as with e.g. adaptive coding for binary treatment BCF). Once a basis has been updated, the overall "function" represented by a tree model has changed and this should be reflected through to the residual before the next sampling loop is run.

Usage:

```
ForestModel$propagate_basis_update(dataset, outcome, active_forest)
```

Arguments:

`dataset` ForestDataset object storing the covariates and bases for a given forest

`outcome` Outcome object storing the residuals to be updated based on forest predictions

`active_forest` "Active" forest updated by the sampler in each iteration

Method `propagate_residual_update()`: Update the current state of the outcome (i.e. partial residual) data by subtracting the current predictions of each tree. This function is run after the Outcome class's `update_data` method, which overwrites the partial residual with an entirely new stream of outcome data.

Usage:

```
ForestModel$propagate_residual_update(residual)
```

Arguments:

`residual` Outcome used to sample the forest

Returns: None

Method `update_alpha()`: Update alpha in the tree prior

Usage:

```
ForestModel$update_alpha(alpha)
```

Arguments:

`alpha` New value of alpha to be used

Returns: None

Method `update_beta()`: Update beta in the tree prior

Usage:

```
ForestModel$update_beta(beta)
```

Arguments:

`beta` New value of beta to be used

Returns: None

Method `update_min_samples_leaf()`: Update `min_samples_leaf` in the tree prior

Usage:

```
ForestModel$update_min_samples_leaf(min_samples_leaf)
```

Arguments:

`min_samples_leaf` New value of `min_samples_leaf` to be used

Returns: None

Method `update_max_depth()`: Update `max_depth` in the tree prior

Usage:

```
ForestModel$update_max_depth(max_depth)
```

Arguments:

`max_depth` New value of `max_depth` to be used

Returns: None

Method `get_alpha()`: Update `alpha` in the tree prior

Usage:

```
ForestModel$get_alpha()
```

Returns: Value of `alpha` in the tree prior

Method `get_beta()`: Update `beta` in the tree prior

Usage:

```
ForestModel$get_beta()
```

Returns: Value of `beta` in the tree prior

Method `get_min_samples_leaf()`: Query `min_samples_leaf` in the tree prior

Usage:

```
ForestModel$get_min_samples_leaf()
```

Returns: Value of `min_samples_leaf` in the tree prior

Method `get_max_depth()`: Query `max_depth` in the tree prior

Usage:

```
ForestModel$get_max_depth()
```

Returns: Value of `max_depth` in the tree prior

ForestModelConfig *Forest Model Configuration Object*

Description

Object used to get / set parameters and other model configuration options for a forest model in the "low-level" stochtree interface. The "low-level" stochtree interface enables a high degree of sampler customization, in which users employ R wrappers around C++ objects like ForestDataset, Outcome, CppRng, and ForestModel to run the Gibbs sampler of a BART model with custom modifications. ForestModelConfig allows users to specify / query the parameters of a forest model they wish to run.

This class is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Value

Vector of integer-coded feature types (integers where 0 = numeric, 1 = ordered categorical, 2 = unordered categorical)

Vector of (0-indexed) indices of trees to update in a sweep

Vector specifying sampling probability for all p covariates in ForestDataset

Number of trees in a forest

Number of features in a forest model training set

Number of observations in a forest model training set

Root node split probability in tree prior

Depth prior penalty in tree prior

Minimum number of samples in a tree leaf

Maximum depth of any tree in the ensemble in the model

Integer coded leaf model type

Scale parameter used in Gaussian leaf models

Shape parameter for IG leaf models

Scale parameter for IG leaf models

Shape parameter for conditional gamma component of cloglog leaf models

Rate parameter for conditional gamma component of cloglog leaf models

Number of unique cutpoints to consider

Number of features to subsample for the GFR algorithm

Public fields

feature_types Vector of integer-coded feature types (integers where 0 = numeric, 1 = ordered categorical, 2 = unordered categorical)
sweep_update_indices Vector of trees to update in a sweep
num_trees Number of trees in the forest being sampled
num_features Number of features in training dataset
num_observations Number of observations in training dataset
leaf_dimension Dimension of the leaf model
alpha Root node split probability in tree prior
beta Depth prior penalty in tree prior
min_samples_leaf Minimum number of samples in a tree leaf
max_depth Maximum depth of any tree in the ensemble in the model. Setting to -1 does not enforce any depth limits on trees.
leaf_model_type Integer specifying the leaf model type (0 = constant leaf, 1 = univariate leaf regression, 2 = multivariate leaf regression)
leaf_model_scale Scale parameter used in Gaussian leaf models
variable_weights Vector specifying sampling probability for all p covariates in ForestDataset
variance_forest_shape Shape parameter for IG leaf models (applicable when leaf_model_type = 3)
variance_forest_scale Scale parameter for IG leaf models (applicable when leaf_model_type = 3)
cloglog_forest_shape Shape parameter for conditional gamma component of cloglog leaf models (applicable when leaf_model_type = 4)
cloglog_forest_rate Rate parameter for conditional gamma component of cloglog leaf models (applicable when leaf_model_type = 4)
cutpoint_grid_size Number of unique cutpoints to consider
num_features_subsample Number of features to subsample for the GFR algorithm Create a new ForestModelConfig object.

Methods**Public methods:**

- [ForestModelConfig\\$new\(\)](#)
- [ForestModelConfig\\$update_feature_types\(\)](#)
- [ForestModelConfig\\$update_sweep_indices\(\)](#)
- [ForestModelConfig\\$update_variable_weights\(\)](#)
- [ForestModelConfig\\$update_alpha\(\)](#)
- [ForestModelConfig\\$update_beta\(\)](#)
- [ForestModelConfig\\$update_min_samples_leaf\(\)](#)
- [ForestModelConfig\\$update_max_depth\(\)](#)
- [ForestModelConfig\\$update_leaf_model_scale\(\)](#)

- ForestModelConfig\$update_variance_forest_shape()
- ForestModelConfig\$update_variance_forest_scale()
- ForestModelConfig\$update_cloglog_forest_shape()
- ForestModelConfig\$update_cloglog_forest_rate()
- ForestModelConfig\$update_cutpoint_grid_size()
- ForestModelConfig\$update_num_features_subsample()
- ForestModelConfig\$get_feature_types()
- ForestModelConfig\$get_sweep_indices()
- ForestModelConfig\$get_variable_weights()
- ForestModelConfig\$get_num_trees()
- ForestModelConfig\$get_num_features()
- ForestModelConfig\$get_num_observations()
- ForestModelConfig\$get_alpha()
- ForestModelConfig\$get_beta()
- ForestModelConfig\$get_min_samples_leaf()
- ForestModelConfig\$get_max_depth()
- ForestModelConfig\$get_leaf_model_type()
- ForestModelConfig\$get_leaf_model_scale()
- ForestModelConfig\$get_variance_forest_shape()
- ForestModelConfig\$get_variance_forest_scale()
- ForestModelConfig\$get_cloglog_forest_shape()
- ForestModelConfig\$get_cloglog_forest_rate()
- ForestModelConfig\$get_cutpoint_grid_size()
- ForestModelConfig\$get_num_features_subsample()

Method new():

Usage:

```
ForestModelConfig$new(
  feature_types = NULL,
  sweep_update_indices = NULL,
  num_trees = NULL,
  num_features = NULL,
  num_observations = NULL,
  variable_weights = NULL,
  leaf_dimension = 1,
  alpha = 0.95,
  beta = 2,
  min_samples_leaf = 5,
  max_depth = -1,
  leaf_model_type = 1,
  leaf_model_scale = NULL,
  variance_forest_shape = 1,
  variance_forest_scale = 1,
  cloglog_forest_shape = 2,
  cloglog_forest_rate = 2,
```

```

    cutpoint_grid_size = 100,
    num_features_subsample = NULL
)

```

Arguments:

feature_types Vector of integer-coded feature types (where 0 = numeric, 1 = ordered categorical, 2 = unordered categorical)

sweep_update_indices Vector of (0-indexed) indices of trees to update in a sweep

num_trees Number of trees in the forest being sampled

num_features Number of features in training dataset

num_observations Number of observations in training dataset

variable_weights Vector specifying sampling probability for all p covariates in ForestDataset

leaf_dimension Dimension of the leaf model (default: 1)

alpha Root node split probability in tree prior (default: 0.95)

beta Depth prior penalty in tree prior (default: 2.0)

min_samples_leaf Minimum number of samples in a tree leaf (default: 5)

max_depth Maximum depth of any tree in the ensemble in the model. Setting to -1 does not enforce any depth limits on trees. Default: -1.

leaf_model_type Integer specifying the leaf model type (0 = constant leaf, 1 = univariate leaf regression, 2 = multivariate leaf regression). Default: 0.

leaf_model_scale Scale parameter used in Gaussian leaf models (can either be a scalar or a $q \times q$ matrix, where q is the dimensionality of the basis and is only >1 when `leaf_model_type` = 2). Calibrated internally as $1/\text{num_trees}$, propagated along diagonal if needed for multivariate leaf models.

variance_forest_shape Shape parameter for IG leaf models (applicable when `leaf_model_type` = 3). Default: 1.

variance_forest_scale Scale parameter for IG leaf models (applicable when `leaf_model_type` = 3). Default: 1.

cloglog_forest_shape Shape parameter for conditional gamma component of cloglog leaf models (applicable when `leaf_model_type` = 4). Default: 1.

cloglog_forest_rate Rate parameter for conditional gamma component of cloglog leaf models (applicable when `leaf_model_type` = 4). Default: 1.

cutpoint_grid_size Number of unique cutpoints to consider (default: 100)

num_features_subsample Number of features to subsample for the GFR algorithm

Returns: A new ForestModelConfig object.

Method `update_feature_types()`: Update feature types

Usage:

```
ForestModelConfig$update_feature_types(feature_types)
```

Arguments:

feature_types Vector of integer-coded feature types (integers where 0 = numeric, 1 = ordered categorical, 2 = unordered categorical)

Method `update_sweep_indices()`: Update sweep update indices

Usage:

ForestModelConfig\$update_sweep_indices(sweep_update_indices)

Arguments:

sweep_update_indices Vector of (0-indexed) indices of trees to update in a sweep

Method update_variable_weights(): Update variable weights

Usage:

ForestModelConfig\$update_variable_weights(variable_weights)

Arguments:

variable_weights Vector specifying sampling probability for all p covariates in ForestDataset

Method update_alpha(): Update root node split probability in tree prior

Usage:

ForestModelConfig\$update_alpha(alpha)

Arguments:

alpha Root node split probability in tree prior

Method update_beta(): Update depth prior penalty in tree prior

Usage:

ForestModelConfig\$update_beta(beta)

Arguments:

beta Depth prior penalty in tree prior

Method update_min_samples_leaf(): Update minimum number of samples per leaf node in the tree prior

Usage:

ForestModelConfig\$update_min_samples_leaf(min_samples_leaf)

Arguments:

min_samples_leaf Minimum number of samples in a tree leaf

Method update_max_depth(): Update max depth in the tree prior

Usage:

ForestModelConfig\$update_max_depth(max_depth)

Arguments:

max_depth Maximum depth of any tree in the ensemble in the model

Method update_leaf_model_scale(): Update scale parameter used in Gaussian leaf models

Usage:

ForestModelConfig\$update_leaf_model_scale(leaf_model_scale)

Arguments:

leaf_model_scale Scale parameter used in Gaussian leaf models

Method update_variance_forest_shape(): Update shape parameter for IG leaf models

Usage:

ForestModelConfig\$update_variance_forest_shape(variance_forest_shape)

Arguments:

variance_forest_shape Shape parameter for IG leaf models

Method update_variance_forest_scale(): Update scale parameter for IG leaf models

Usage:

ForestModelConfig\$update_variance_forest_scale(variance_forest_scale)

Arguments:

variance_forest_scale Scale parameter for IG leaf models

Method update_cloglog_forest_shape(): Update shape parameter for conditional gamma component of cloglog leaf models

Usage:

ForestModelConfig\$update_cloglog_forest_shape(cloglog_forest_shape)

Arguments:

cloglog_forest_shape Shape parameter for conditional gamma component of cloglog leaf models

Method update_cloglog_forest_rate(): Update rate parameter for conditional gamma component of cloglog leaf models

Usage:

ForestModelConfig\$update_cloglog_forest_rate(cloglog_forest_rate)

Arguments:

cloglog_forest_rate Rate parameter for conditional gamma component of cloglog leaf models

Method update_cutpoint_grid_size(): Update number of unique cutpoints to consider

Usage:

ForestModelConfig\$update_cutpoint_grid_size(cutpoint_grid_size)

Arguments:

cutpoint_grid_size Number of unique cutpoints to consider

Method update_num_features_subsample(): Update number of features to subsample for the GFR algorithm

Usage:

ForestModelConfig\$update_num_features_subsample(num_features_subsample)

Arguments:

num_features_subsample Number of features to subsample for the GFR algorithm

Method get_feature_types(): Query feature types for this ForestModelConfig object

Usage:

ForestModelConfig\$get_feature_types()

Method get_sweep_indices(): Query sweep update indices for this ForestModelConfig object

Usage:

ForestModelConfig\$get_sweep_indices()

Method get_variable_weights(): Query variable weights for this ForestModelConfig object

Usage:

ForestModelConfig\$get_variable_weights()

Method get_num_trees(): Query number of trees

Usage:

ForestModelConfig\$get_num_trees()

Method get_num_features(): Query number of features

Usage:

ForestModelConfig\$get_num_features()

Method get_num_observations(): Query number of observations

Usage:

ForestModelConfig\$get_num_observations()

Method get_alpha(): Query root node split probability in tree prior for this ForestModelConfig object

Usage:

ForestModelConfig\$get_alpha()

Method get_beta(): Query depth prior penalty in tree prior for this ForestModelConfig object

Usage:

ForestModelConfig\$get_beta()

Method get_min_samples_leaf(): Query root node split probability in tree prior for this ForestModelConfig object

Usage:

ForestModelConfig\$get_min_samples_leaf()

Method get_max_depth(): Query root node split probability in tree prior for this ForestModelConfig object

Usage:

ForestModelConfig\$get_max_depth()

Method get_leaf_model_type(): Query (integer-coded) type of leaf model

Usage:

ForestModelConfig\$get_leaf_model_type()

Method get_leaf_model_scale(): Query scale parameter used in Gaussian leaf models for this ForestModelConfig object

Usage:

ForestModelConfig\$get_leaf_model_scale()

Method `get_variance_forest_shape()`: Query shape parameter for IG leaf models for this `ForestModelConfig` object

Usage:

`ForestModelConfig$get_variance_forest_shape()`

Method `get_variance_forest_scale()`: Query scale parameter for IG leaf models for this `ForestModelConfig` object

Usage:

`ForestModelConfig$get_variance_forest_scale()`

Method `get_cloglog_forest_shape()`: Query shape parameter for conditional gamma component of cloglog leaf models for this `ForestModelConfig` object

Usage:

`ForestModelConfig$get_cloglog_forest_shape()`

Method `get_cloglog_forest_rate()`: Query rate parameter for conditional gamma component of cloglog leaf models for this `ForestModelConfig` object

Usage:

`ForestModelConfig$get_cloglog_forest_rate()`

Method `get_cutpoint_grid_size()`: Query number of unique cutpoints to consider for this `ForestModelConfig` object

Usage:

`ForestModelConfig$get_cutpoint_grid_size()`

Method `get_num_features_subsample()`: Query number of features to subsample for the GFR algorithm

Usage:

`ForestModelConfig$get_num_features_subsample()`

ForestSamples

Forest Container C++ Wrapper

Description

Wrapper around a C++ class that stores draws from an random ensemble of decision trees.

This class is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Public fields

`forest_container_ptr` External pointer to a C++ `ForestContainer` class

Methods**Public methods:**

- `ForestSamples$new()`
- `ForestSamples$collapse()`
- `ForestSamples$combine_forests()`
- `ForestSamples$add_to_forest()`
- `ForestSamples$multiply_forest()`
- `ForestSamples$load_from_json()`
- `ForestSamples$append_from_json()`
- `ForestSamples$load_from_json_string()`
- `ForestSamples$append_from_json_string()`
- `ForestSamples$predict()`
- `ForestSamples$predict_raw()`
- `ForestSamples$predict_raw_single_forest()`
- `ForestSamples$predict_raw_single_tree()`
- `ForestSamples$set_root_leaves()`
- `ForestSamples$prepare_for_sampler()`
- `ForestSamples$adjust_residual()`
- `ForestSamples$save_json()`
- `ForestSamples$load_json()`
- `ForestSamples$num_samples()`
- `ForestSamples$num_trees()`
- `ForestSamples$leaf_dimension()`
- `ForestSamples$is_leaf_constant()`
- `ForestSamples$is_exponentiated()`
- `ForestSamples$add_forest_with_constant_leaves()`
- `ForestSamples$add_numeric_split_tree()`
- `ForestSamples$get_tree_leaves()`
- `ForestSamples$get_tree_split_counts()`
- `ForestSamples$get_forest_split_counts()`
- `ForestSamples$get_aggregate_split_counts()`
- `ForestSamples$get_granular_split_counts()`
- `ForestSamples$ensemble_tree_max_depth()`
- `ForestSamples$average_ensemble_max_depth()`
- `ForestSamples$average_max_depth()`
- `ForestSamples$num_forest_leaves()`
- `ForestSamples$sum_leaves_squared()`
- `ForestSamples$is_leaf_node()`
- `ForestSamples$is_numeric_split_node()`
- `ForestSamples$is_categorical_split_node()`
- `ForestSamples$parent_node()`
- `ForestSamples$left_child_node()`

- `ForestSamples$right_child_node()`
- `ForestSamples$node_depth()`
- `ForestSamples$node_split_index()`
- `ForestSamples$node_split_threshold()`
- `ForestSamples$node_split_categories()`
- `ForestSamples$node_leaf_values()`
- `ForestSamples$num_nodes()`
- `ForestSamples$num_leaves()`
- `ForestSamples$num_leaf_parents()`
- `ForestSamples$num_split_nodes()`
- `ForestSamples$nodes()`
- `ForestSamples$leaves()`
- `ForestSamples$delete_sample()`

Method `new()`: Create a new `ForestContainer` object.

Usage:

```
ForestSamples$new(
  num_trees,
  leaf_dimension = 1,
  is_leaf_constant = FALSE,
  is_exponentiated = FALSE
)
```

Arguments:

`num_trees` Number of trees

`leaf_dimension` Dimensionality of the outcome model

`is_leaf_constant` Whether leaf is constant

`is_exponentiated` Whether forest predictions should be exponentiated before being returned

Returns: A new `ForestContainer` object.

Method `collapse()`: Collapse forests in this container by a pre-specified batch size. For example, if we have a container of twenty 10-tree forests, and we specify a `batch_size` of 5, then this method will yield four 50-tree forests. "Excess" forests remaining after the size of a forest container is divided by `batch_size` will be pruned from the beginning of the container (i.e. earlier sampled forests will be deleted). This method has no effect if `batch_size` is larger than the number of forests in a container.

Usage:

```
ForestSamples$collapse(batch_size)
```

Arguments:

`batch_size` Number of forests to be collapsed into a single forest

Method `combine_forests()`: Merge specified forests into a single forest

Usage:

```
ForestSamples$combine_forests(forest_inds)
```

Arguments:

forest_inds Indices of forests to be combined (0-indexed)

Method add_to_forest(): Add a constant value to every leaf of every tree of a given forest

Usage:

```
ForestSamples$add_to_forest(forest_index, constant_value)
```

Arguments:

forest_index Index of forest whose leaves will be modified (0-indexed)

constant_value Value to add to every leaf of every tree of the forest at forest_index

Method multiply_forest(): Multiply every leaf of every tree of a given forest by constant value

Usage:

```
ForestSamples$multiply_forest(forest_index, constant_multiple)
```

Arguments:

forest_index Index of forest whose leaves will be modified (0-indexed)

constant_multiple Value to multiply through by every leaf of every tree of the forest at forest_index

Method load_from_json(): Create a new ForestContainer object from a json object

Usage:

```
ForestSamples$load_from_json(json_object, json_forest_label)
```

Arguments:

json_object Object of class CppJson

json_forest_label Label referring to a particular forest (i.e. "forest_0") in the overall json hierarchy

Returns: A new ForestContainer object.

Method append_from_json(): Append to a ForestContainer object from a json object

Usage:

```
ForestSamples$append_from_json(json_object, json_forest_label)
```

Arguments:

json_object Object of class CppJson

json_forest_label Label referring to a particular forest (i.e. "forest_0") in the overall json hierarchy

Returns: None

Method load_from_json_string(): Create a new ForestContainer object from a json object

Usage:

```
ForestSamples$load_from_json_string(json_string, json_forest_label)
```

Arguments:

json_string JSON string which parses into object of class CppJson

`json_forest_label` Label referring to a particular forest (i.e. "forest_0") in the overall json hierarchy

Returns: A new ForestContainer object.

Method `append_from_json_string()`: Append to a ForestContainer object from a json object

Usage:

`ForestSamples$append_from_json_string(json_string, json_forest_label)`

Arguments:

`json_string` JSON string which parses into object of class CppJson

`json_forest_label` Label referring to a particular forest (i.e. "forest_0") in the overall json hierarchy

Returns: None

Method `predict()`: Predict every tree ensemble on every sample in `forest_dataset`

Usage:

`ForestSamples$predict(forest_dataset)`

Arguments:

`forest_dataset` ForestDataset R class

Returns: matrix of predictions with as many rows as in `forest_dataset` and as many columns as samples in the ForestContainer

Method `predict_raw()`: Predict "raw" leaf values (without being multiplied by basis) for every tree ensemble on every sample in `forest_dataset`

Usage:

`ForestSamples$predict_raw(forest_dataset)`

Arguments:

`forest_dataset` ForestDataset R class

Returns: Array of predictions for each observation in `forest_dataset` and each sample in the ForestSamples class with each prediction having the dimensionality of the forests' leaf model. In the case of a constant leaf model or univariate leaf regression, this array is two-dimensional (number of observations, number of forest samples). In the case of a multivariate leaf regression, this array is three-dimension (number of observations, leaf model dimension, number of samples).

Method `predict_raw_single_forest()`: Predict "raw" leaf values (without being multiplied by basis) for a specific forest on every sample in `forest_dataset`

Usage:

`ForestSamples$predict_raw_single_forest(forest_dataset, forest_num)`

Arguments:

`forest_dataset` ForestDataset R class

`forest_num` Index of the forest sample within the container

Returns: matrix of predictions with as many rows as in forest_dataset and as many columns as dimensions in the leaves of trees in ForestContainer

Method predict_raw_single_tree(): Predict "raw" leaf values (without being multiplied by basis) for a specific tree in a specific forest on every observation in forest_dataset

Usage:

```
ForestSamples$predict_raw_single_tree(forest_dataset, forest_num, tree_num)
```

Arguments:

forest_dataset ForestDataset R class

forest_num Index of the forest sample within the container

tree_num Index of the tree to be queried

Returns: matrix of predictions with as many rows as in forest_dataset and as many columns as dimensions in the leaves of trees in ForestContainer

Method set_root_leaves(): Set a constant predicted value for every tree in the ensemble. Stops program if any tree is more than a root node.

Usage:

```
ForestSamples$set_root_leaves(forest_num, leaf_value)
```

Arguments:

forest_num Index of the forest sample within the container.

leaf_value Constant leaf value(s) to be fixed for each tree in the ensemble indexed by forest_num.
Can be either a single number or a vector, depending on the forest's leaf dimension.

Method prepare_for_sampler(): Set a constant predicted value for every tree in the ensemble. Stops program if any tree is more than a root node.

Usage:

```
ForestSamples$prepare_for_sampler(
  dataset,
  outcome,
  forest_model,
  leaf_model_int,
  leaf_value
)
```

Arguments:

dataset ForestDataset Dataset class (covariates, basis, etc...)

outcome Outcome Outcome class (residual / partial residual)

forest_model ForestModel object storing tracking structures used in training / sampling

leaf_model_int Integer value encoding the leaf model type (0 = constant gaussian, 1 = univariate gaussian, 2 = multivariate gaussian, 3 = log linear variance).

leaf_value Constant leaf value(s) to be fixed for each tree in the ensemble indexed by forest_num.
Can be either a single number or a vector, depending on the forest's leaf dimension.

Method adjust_residual(): Adjusts residual based on the predictions of a forest
This is typically run just once at the beginning of a forest sampling algorithm. After trees are initialized with constant root node predictions, their root predictions are subtracted out of the residual.

Usage:

```
ForestSamples$adjust_residual(
  dataset,
  outcome,
  forest_model,
  requires_basis,
  forest_num,
  add
)
```

Arguments:

dataset ForestDataset object storing the covariates and bases for a given forest
 outcome Outcome object storing the residuals to be updated based on forest predictions
 forest_model ForestModel object storing tracking structures used in training / sampling
 requires_basis Whether or not a forest requires a basis for prediction
 forest_num Index of forest used to update residuals
 add Whether forest predictions should be added to or subtracted from residuals

Method save_json(): Store the trees and metadata of ForestDataset class in a json file

Usage:

```
ForestSamples$save_json(json_filename)
```

Arguments:

json_filename Name of output json file (must end in ".json")

Method load_json(): Load trees and metadata for an ensemble from a json file. Note that any trees and metadata already present in ForestDataset class will be overwritten.

Usage:

```
ForestSamples$load_json(json_filename)
```

Arguments:

json_filename Name of model input json file (must end in ".json")

Method num_samples(): Return number of samples in a ForestContainer object

Usage:

```
ForestSamples$num_samples()
```

Returns: Sample count

Method num_trees(): Return number of trees in each ensemble of a ForestContainer object

Usage:

```
ForestSamples$num_trees()
```

Returns: Tree count

Method leaf_dimension(): Return output dimension of trees in a ForestContainer object

Usage:

```
ForestSamples$leaf_dimension()
```

Returns: Leaf node parameter size

Method `is_leaf_constant()`: Return constant leaf status of trees in a ForestContainer object

Usage:

```
ForestSamples$is_leaf_constant()
```

Returns: TRUE if leaves are constant, FALSE otherwise

Method `is_exponentiated()`: Return exponentiation status of trees in a ForestContainer object

Usage:

```
ForestSamples$is_exponentiated()
```

Returns: TRUE if leaf predictions must be exponentiated, FALSE otherwise

Method `add_forest_with_constant_leaves()`: Add a new all-root ensemble to the container, with all of the leaves set to the value / vector provided

Usage:

```
ForestSamples$add_forest_with_constant_leaves(leaf_value)
```

Arguments:

`leaf_value` Value (or vector of values) to initialize root nodes in tree

Method `add_numeric_split_tree()`: Add a numeric (i.e. $X[,i] \leq c$) split to a given tree in the ensemble

Usage:

```
ForestSamples$add_numeric_split_tree(
  forest_num,
  tree_num,
  leaf_num,
  feature_num,
  split_threshold,
  left_leaf_value,
  right_leaf_value
)
```

Arguments:

`forest_num` Index of the forest which contains the tree to be split

`tree_num` Index of the tree to be split

`leaf_num` Leaf to be split

`feature_num` Feature that defines the new split

`split_threshold` Value that defines the cutoff of the new split

`left_leaf_value` Value (or vector of values) to assign to the newly created left node

`right_leaf_value` Value (or vector of values) to assign to the newly created right node

Method `get_tree_leaves()`: Retrieve a vector of indices of leaf nodes for a given tree in a given forest

Usage:

```
ForestSamples$get_tree_leaves(forest_num, tree_num)
```

Arguments:

forest_num Index of the forest which contains tree tree_num
 tree_num Index of the tree for which leaf indices will be retrieved

Method `get_tree_split_counts()`: Retrieve a vector of split counts for every training set variable in a given tree in a given forest

Usage:

```
ForestSamples$get_tree_split_counts(forest_num, tree_num, num_features)
```

Arguments:

forest_num Index of the forest which contains tree tree_num
 tree_num Index of the tree for which split counts will be retrieved
 num_features Total number of features in the training set

Method `get_forest_split_counts()`: Retrieve a vector of split counts for every training set variable in a given forest

Usage:

```
ForestSamples$get_forest_split_counts(forest_num, num_features)
```

Arguments:

forest_num Index of the forest for which split counts will be retrieved
 num_features Total number of features in the training set

Method `get_aggregate_split_counts()`: Retrieve a vector of split counts for every training set variable in a given forest, aggregated across ensembles and trees

Usage:

```
ForestSamples$get_aggregate_split_counts(num_features)
```

Arguments:

num_features Total number of features in the training set

Method `get_granular_split_counts()`: Retrieve a vector of split counts for every training set variable in a given forest, reported separately for each ensemble and tree

Usage:

```
ForestSamples$get_granular_split_counts(num_features)
```

Arguments:

num_features Total number of features in the training set

Method `ensemble_tree_max_depth()`: Maximum depth of a specific tree in a specific ensemble in a ForestSamples object

Usage:

```
ForestSamples$ensemble_tree_max_depth(ensemble_num, tree_num)
```

Arguments:

ensemble_num Ensemble number

tree_num Tree index within ensemble ensemble_num

Returns: Maximum leaf depth

Method average_ensemble_max_depth(): Average the maximum depth of each tree in a given ensemble in a ForestSamples object

Usage:

ForestSamples\$average_ensemble_max_depth(ensemble_num)

Arguments:

ensemble_num Ensemble number

Returns: Average maximum depth

Method average_max_depth(): Average the maximum depth of each tree in each ensemble in a ForestContainer object

Usage:

ForestSamples\$average_max_depth()

Returns: Average maximum depth

Method num_forest_leaves(): Number of leaves in a given ensemble in a ForestSamples object

Usage:

ForestSamples\$num_forest_leaves(forest_num)

Arguments:

forest_num Index of the ensemble to be queried

Returns: Count of leaves in the ensemble stored at forest_num

Method sum_leaves_squared(): Sum of squared (raw) leaf values in a given ensemble in a ForestSamples object

Usage:

ForestSamples\$sum_leaves_squared(forest_num)

Arguments:

forest_num Index of the ensemble to be queried

Returns: Average maximum depth

Method is_leaf_node(): Whether or not a given node of a given tree in a given forest in the ForestSamples is a leaf

Usage:

ForestSamples\$is_leaf_node(forest_num, tree_num, node_id)

Arguments:

forest_num Index of the forest to be queried

tree_num Index of the tree to be queried

node_id Index of the node to be queried

Returns: TRUE if node is a leaf, FALSE otherwise

Method `is_numeric_split_node()`: Whether or not a given node of a given tree in a given forest in the ForestSamples is a numeric split node

Usage:

```
ForestSamples$is_numeric_split_node(forest_num, tree_num, node_id)
```

Arguments:

`forest_num` Index of the forest to be queried

`tree_num` Index of the tree to be queried

`node_id` Index of the node to be queried

Returns: TRUE if node is a numeric split node, FALSE otherwise

Method `is_categorical_split_node()`: Whether or not a given node of a given tree in a given forest in the ForestSamples is a categorical split node

Usage:

```
ForestSamples$is_categorical_split_node(forest_num, tree_num, node_id)
```

Arguments:

`forest_num` Index of the forest to be queried

`tree_num` Index of the tree to be queried

`node_id` Index of the node to be queried

Returns: TRUE if node is a categorical split node, FALSE otherwise

Method `parent_node()`: Parent node of given node of a given tree in a given forest in a ForestSamples object

Usage:

```
ForestSamples$parent_node(forest_num, tree_num, node_id)
```

Arguments:

`forest_num` Index of the forest to be queried

`tree_num` Index of the tree to be queried

`node_id` Index of the node to be queried

Returns: Integer ID of the parent node

Method `left_child_node()`: Left child node of given node of a given tree in a given forest in a ForestSamples object

Usage:

```
ForestSamples$left_child_node(forest_num, tree_num, node_id)
```

Arguments:

`forest_num` Index of the forest to be queried

`tree_num` Index of the tree to be queried

`node_id` Index of the node to be queried

Returns: Integer ID of the left child node

Method `right_child_node()`: Right child node of given node of a given tree in a given forest in a ForestSamples object

Usage:

```
ForestSamples$right_child_node(forest_num, tree_num, node_id)
```

Arguments:

forest_num Index of the forest to be queried

tree_num Index of the tree to be queried

node_id Index of the node to be queried

Returns: Integer ID of the right child node

Method node_depth(): Depth of given node of a given tree in a given forest in a ForestSamples object, with 0 depth for the root node.

Usage:

```
ForestSamples$node_depth(forest_num, tree_num, node_id)
```

Arguments:

forest_num Index of the forest to be queried

tree_num Index of the tree to be queried

node_id Index of the node to be queried

Returns: Integer valued depth of the node

Method node_split_index(): Split index of given node of a given tree in a given forest in a ForestSamples object. Returns -1 if node is a leaf.

Usage:

```
ForestSamples$node_split_index(forest_num, tree_num, node_id)
```

Arguments:

forest_num Index of the forest to be queried

tree_num Index of the tree to be queried

node_id Index of the node to be queried

Returns: Integer valued depth of the node

Method node_split_threshold(): Threshold that defines a numeric split for a given node of a given tree in a given forest in a ForestSamples object. Returns Inf if the node is a leaf or a categorical split node.

Usage:

```
ForestSamples$node_split_threshold(forest_num, tree_num, node_id)
```

Arguments:

forest_num Index of the forest to be queried

tree_num Index of the tree to be queried

node_id Index of the node to be queried

Returns: Threshold defining a split for the node

Method node_split_categories(): Array of category indices that define a categorical split for a given node of a given tree in a given forest in a ForestSamples object. Returns c(Inf) if the node is a leaf or a numeric split node.

Usage:

```
ForestSamples$node_split_categories(forest_num, tree_num, node_id)
```

Arguments:

forest_num Index of the forest to be queried

tree_num Index of the tree to be queried

node_id Index of the node to be queried

Returns: Categories defining a split for the node

Method node_leaf_values(): Leaf node value(s) for a given node of a given tree in a given forest in a ForestSamples object. Values are stale if the node is a split node.

Usage:

```
ForestSamples$node_leaf_values(forest_num, tree_num, node_id)
```

Arguments:

forest_num Index of the forest to be queried

tree_num Index of the tree to be queried

node_id Index of the node to be queried

Returns: Vector (often univariate) of leaf values

Method num_nodes(): Number of nodes in a given tree in a given forest in a ForestSamples object.

Usage:

```
ForestSamples$num_nodes(forest_num, tree_num)
```

Arguments:

forest_num Index of the forest to be queried

tree_num Index of the tree to be queried

Returns: Count of total tree nodes

Method num_leaves(): Number of leaves in a given tree in a given forest in a ForestSamples object.

Usage:

```
ForestSamples$num_leaves(forest_num, tree_num)
```

Arguments:

forest_num Index of the forest to be queried

tree_num Index of the tree to be queried

Returns: Count of total tree leaves

Method num_leaf_parents(): Number of leaf parents (split nodes with two leaves as children) in a given tree in a given forest in a ForestSamples object.

Usage:

```
ForestSamples$num_leaf_parents(forest_num, tree_num)
```

Arguments:

forest_num Index of the forest to be queried

tree_num Index of the tree to be queried

Returns: Count of total tree leaf parents

Method num_split_nodes(): Number of split nodes in a given tree in a given forest in a ForestSamples object.

Usage:

ForestSamples\$num_split_nodes(forest_num, tree_num)

Arguments:

forest_num Index of the forest to be queried

tree_num Index of the tree to be queried

Returns: Count of total tree split nodes

Method nodes(): Array of node indices in a given tree in a given forest in a ForestSamples object.

Usage:

ForestSamples\$nodes(forest_num, tree_num)

Arguments:

forest_num Index of the forest to be queried

tree_num Index of the tree to be queried

Returns: Indices of tree nodes

Method leaves(): Array of leaf indices in a given tree in a given forest in a ForestSamples object.

Usage:

ForestSamples\$leaves(forest_num, tree_num)

Arguments:

forest_num Index of the forest to be queried

tree_num Index of the tree to be queried

Returns: Indices of leaf nodes

Method delete_sample(): Modify the ForestSamples object by removing the forest sample indexed by 'forest_num

Usage:

ForestSamples\$delete_sample(forest_num)

Arguments:

forest_num Index of the forest to be removed

ForestSamplesSerialization*Forest Container Serialization Routines*

Description

While the [BARTSerialization](#) and [BCFSerialization](#) topics focus on JSON serialization / deserialization for entire `bartmodel` and `bcfmodel` objects, this function group provides an interface for a more focused use case: loading a single [ForestSamples](#) container from a broader BART / BCF model (which may include multiple forests and other parametric terms).

`loadForestContainerJson` converts a [CppJson](#) object representing a BART or BCF model into a [ForestSamples](#) container by extracting the JSON indexed by a forest label (i.e. "forest_0") and deserializing it into a [ForestSamples](#) object.

Both `loadForestContainerJson` and `loadForestContainerCombinedJson` operate similarly, but on a list of [CppJson](#) or JSON string representations of BART / BCF models with the same structure.

These functions are intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the `stochtree`'s advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Usage

```
loadForestContainerJson(json_object, json_forest_label)
```

```
loadForestContainerCombinedJson(json_object_list, json_forest_label)
```

```
loadForestContainerCombinedJsonString(json_string_list, json_forest_label)
```

Arguments

`json_object` Object of class `CppJson`

`json_forest_label`

Label referring to a particular forest (i.e. "forest_0") in the overall json hierarchy (must exist in every json object in a list if a list is provided)

`json_object_list`

List of objects of class `CppJson`

`json_string_list`

List of strings that parse into objects of type `CppJson`

Value

Each of the functions in this group returns a `ForestSamples` object.

Examples

```
X <- matrix(runif(10*100), ncol = 10)
y <- -5 + 10*(X[,1] > 0.5) + rnorm(100)
bart_model <- bart(X, y, num_gfr=0, num_mcmc=10)
bart_json <- saveBARTModelToJson(bart_model)
bart_json_string <- saveBARTModelToJsonString(bart_model)
bart_json_list <- list(bart_json)
bart_json_string_list <- list(bart_json_string)
mean_forest <- loadForestContainerJson(bart_json, "forest_0")
mean_forest <- loadForestContainerCombinedJson(bart_json_list, "forest_0")
mean_forest <- loadForestContainerCombinedJsonString(bart_json_string_list, "forest_0")
```

ForestStateManagement *Forest State Management Routines*

Description

A forest sampler features two types of state: ephemeral and persistent. Persistent state includes objects like [ForestSamples](#) and [RandomEffectSamples](#) which constitute part of the final sampled model. Ephemeral state supports the sampling computations, but is not retained after the sampler finishes.

The two primary forest-based bits of ephemeral state are the [Forest](#) and [ForestModel](#) classes, which represent the current state of a forest and its corresponding tracking data structures.

In a linear sampling loop, this ephemeral state is updated with each iteration of the sampler and any retained forests are copied to a [ForestSamples](#) object. However, in multi-chain settings, the state of a forest must typically be "reset" at the beginning of a new chain. These functions enable this process by synchronizing the state of a [Forest](#) and [ForestModel](#) with a corresponding element of a [ForestSamples](#) object, or by resetting both to their default (root) state.

`resetActiveForest` resets a [Forest](#) object, either from a specific forest in a [ForestSamples](#) object or to an ensemble of single-node (i.e. root) trees. `resetForestModel` re-initializes a forest model (tracking data structures) from a specific forest in a [ForestSamples](#) object.

These functions are intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the `stochtree`'s advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Usage

```
resetActiveForest(active_forest, forest_samples = NULL, forest_num = NULL)

resetForestModel(forest_model, forest, dataset, residual, is_mean_model)
```



```

max_depth=max_depth,
variable_weights=variable_weights,
cutpoint_grid_size=cutpoint_grid_size,
leaf_model_type=leaf_model,
leaf_model_scale=leaf_scale)
forest_model <- createForestModel(forest_dataset, forest_model_config, global_model_config)
active_forest <- createForest(num_trees, leaf_dimension, is_leaf_constant, is_exponentiated)
forest_samples <- createForestSamples(num_trees, leaf_dimension,
                                     is_leaf_constant, is_exponentiated)
active_forest$prepare_for_sampler(forest_dataset, outcome, forest_model, 0, 0.)
forest_model$sample_one_iteration(
  forest_dataset, outcome, forest_samples, active_forest,
  rng, forest_model_config, global_model_config,
  keep_forest = TRUE, gfr = FALSE
)
resetActiveForest(active_forest, forest_samples, 0)
resetForestModel(forest_model, active_forest, forest_dataset, outcome, TRUE)

```

getRandomEffectSamples

Extract Random Effect Samples Generic Function

Description

Generic function for extracting random effect samples from a model object (BCF, BART, etc...)

Usage

```
getRandomEffectSamples(object, ...)
```

Arguments

object	Fitted model object from which to extract random effects
...	Other parameters to be used in random effects extraction

Value

List of random effect samples

Examples

```

n <- 100
p <- 10
X <- matrix(runif(n*p), ncol = p)
rfx_group_ids <- sample(1:2, size = n, replace = TRUE)
rfx_basis <- rep(1.0, n)
y <- (-5 + 10*(X[,1] > 0.5)) + (-2*(rfx_group_ids==1)+2*(rfx_group_ids==2)) + rnorm(n)
bart_model <- bart(X_train=X, y_train=y, rfx_group_ids_train=rfx_group_ids,
                  rfx_basis_train = rfx_basis, num_gfr=0, num_mcmc=10)
rfx_samples <- getRandomEffectSamples(bart_model)

```

```
getRandomEffectSamples.bartmodel
```

Extract Random Effects Samples from BART Model

Description

Extract raw sample values for each of the random effect parameter terms.

Usage

```
## S3 method for class 'bartmodel'
getRandomEffectSamples(object, ...)
```

Arguments

object	Object of type bartmodel containing draws of a BART model and associated sampling outputs.
...	Other parameters to be used in random effects extraction

Value

List of arrays. The alpha array has dimension (num_components, num_samples) and is simply a vector if num_components = 1. The xi and beta arrays have dimension (num_components, num_groups, num_samples) and is simply a matrix if num_components = 1. The sigma array has dimension (num_components, num_samples) and is simply a vector if num_components = 1.

Examples

```
n <- 100
p <- 5
X <- matrix(runif(n*p), ncol = p)
f_XW <- (
  ((0 <= X[,1]) & (0.25 > X[,1])) * (-7.5) +
  ((0.25 <= X[,1]) & (0.5 > X[,1])) * (-2.5) +
  ((0.5 <= X[,1]) & (0.75 > X[,1])) * (2.5) +
  ((0.75 <= X[,1]) & (1 > X[,1])) * (7.5)
)
snr <- 3
group_ids <- rep(c(1,2), n %% 2)
rfx_coefs <- matrix(c(-1, -1, 1, 1), nrow=2, byrow=TRUE)
rfx_basis <- cbind(1, runif(n, -1, 1))
rfx_term <- rowSums(rfx_coefs[group_ids,] * rfx_basis)
E_y <- f_XW + rfx_term
y <- E_y + rnorm(n, 0, 1)*(sd(E_y)/snr)
test_set_pct <- 0.2
n_test <- round(test_set_pct*n)
n_train <- n - n_test
test_inds <- sort(sample(1:n, n_test, replace = FALSE))
train_inds <- (1:n)[!((1:n) %in% test_inds)]
```

```

X_test <- X[test_inds,]
X_train <- X[train_inds,]
y_test <- y[test_inds]
y_train <- y[train_inds]
rfx_group_ids_test <- group_ids[test_inds]
rfx_group_ids_train <- group_ids[train_inds]
rfx_basis_test <- rfx_basis[test_inds,]
rfx_basis_train <- rfx_basis[train_inds,]
rfx_term_test <- rfx_term[test_inds]
rfx_term_train <- rfx_term[train_inds]
bart_model <- bart(X_train = X_train, y_train = y_train, X_test = X_test,
                  rfx_group_ids_train = rfx_group_ids_train,
                  rfx_group_ids_test = rfx_group_ids_test,
                  rfx_basis_train = rfx_basis_train,
                  rfx_basis_test = rfx_basis_test,
                  num_gfr = 10, num_burnin = 0, num_mcmc = 10)
rfx_samples <- getRandomEffectSamples(bart_model)

```

```
getRandomEffectSamples.bcfmodel
```

Extract Random Effect Samples from BCF Model

Description

Extract raw sample values for each of the random effect parameter terms.

Usage

```
## S3 method for class 'bcfmodel'
getRandomEffectSamples(object, ...)
```

Arguments

object	Object of type <code>bcfmodel</code> containing draws of a Bayesian causal forest model and associated sampling outputs.
...	Other parameters to be used in random effects extraction

Value

List of arrays. The alpha array has dimension $(\text{num_components}, \text{num_samples})$ and is simply a vector if $\text{num_components} = 1$. The xi and beta arrays have dimension $(\text{num_components}, \text{num_groups}, \text{num_samples})$ and is simply a matrix if $\text{num_components} = 1$. The sigma array has dimension $(\text{num_components}, \text{num_samples})$ and is simply a vector if $\text{num_components} = 1$.

Examples

```

n <- 500
p <- 5
X <- matrix(runif(n*p), ncol = p)
mu_x <- (
  ((0 <= X[,1]) & (0.25 > X[,1])) * (-7.5) +
  ((0.25 <= X[,1]) & (0.5 > X[,1])) * (-2.5) +
  ((0.5 <= X[,1]) & (0.75 > X[,1])) * (2.5) +
  ((0.75 <= X[,1]) & (1 > X[,1])) * (7.5)
)
pi_x <- (
  ((0 <= X[,1]) & (0.25 > X[,1])) * (0.2) +
  ((0.25 <= X[,1]) & (0.5 > X[,1])) * (0.4) +
  ((0.5 <= X[,1]) & (0.75 > X[,1])) * (0.6) +
  ((0.75 <= X[,1]) & (1 > X[,1])) * (0.8)
)
tau_x <- (
  ((0 <= X[,2]) & (0.25 > X[,2])) * (0.5) +
  ((0.25 <= X[,2]) & (0.5 > X[,2])) * (1.0) +
  ((0.5 <= X[,2]) & (0.75 > X[,2])) * (1.5) +
  ((0.75 <= X[,2]) & (1 > X[,2])) * (2.0)
)
Z <- rbinom(n, 1, pi_x)
E_XZ <- mu_x + Z*tau_x
snr <- 3
rfx_group_ids <- rep(c(1,2), n %% 2)
rfx_coefs <- matrix(c(-1, -1, 1, 1), nrow=2, byrow=TRUE)
rfx_basis <- cbind(1, runif(n, -1, 1))
rfx_term <- rowSums(rfx_coefs[rfx_group_ids,] * rfx_basis)
y <- E_XZ + rfx_term + rnorm(n, 0, 1)*(sd(E_XZ)/snr)
test_set_pct <- 0.2
n_test <- round(test_set_pct*n)
n_train <- n - n_test
test_inds <- sort(sample(1:n, n_test, replace = FALSE))
train_inds <- (1:n)[!((1:n) %in% test_inds)]
X_test <- X[test_inds,]
X_train <- X[train_inds,]
pi_test <- pi_x[test_inds]
pi_train <- pi_x[train_inds]
Z_test <- Z[test_inds]
Z_train <- Z[train_inds]
y_test <- y[test_inds]
y_train <- y[train_inds]
mu_test <- mu_x[test_inds]
mu_train <- mu_x[train_inds]
tau_test <- tau_x[test_inds]
tau_train <- tau_x[train_inds]
rfx_group_ids_test <- rfx_group_ids[test_inds]
rfx_group_ids_train <- rfx_group_ids[train_inds]
rfx_basis_test <- rfx_basis[test_inds,]
rfx_basis_train <- rfx_basis[train_inds,]
rfx_term_test <- rfx_term[test_inds]

```

```

rfx_term_train <- rfx_term[train_inds]
mu_params <- list(sample_sigma2_leaf = TRUE)
tau_params <- list(sample_sigma2_leaf = FALSE)
bcf_model <- bcf(X_train = X_train, Z_train = Z_train, y_train = y_train,
  propensity_train = pi_train,
  rfx_group_ids_train = rfx_group_ids_train,
  rfx_basis_train = rfx_basis_train, X_test = X_test,
  Z_test = Z_test, propensity_test = pi_test,
  rfx_group_ids_test = rfx_group_ids_test,
  rfx_basis_test = rfx_basis_test,
  num_gfr = 10, num_burnin = 0, num_mcmc = 10,
  prognostic_forest_params = mu_params,
  treatment_effect_forest_params = tau_params)
rfx_samples <- getRandomEffectSamples(bcf_model)

```

GlobalModelConfig

Global Model Configuration Object

Description

Object used to get / set global parameters and other global model configuration options in the "low-level" stochtree interface. The "low-level" stochtree interface enables a high degree of sampler customization, in which users employ R wrappers around C++ objects like ForestDataset, Outcome, CppRng, and ForestModel to run the Gibbs sampler of a BART model with custom modifications. GlobalModelConfig allows users to specify / query the global parameters of a model they wish to run.

This class is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Value

Global error variance parameter

Public fields

`global_error_variance` Global error variance parameter Create a new GlobalModelConfig object.

Methods

Public methods:

- `GlobalModelConfig$new()`
- `GlobalModelConfig$update_global_error_variance()`
- `GlobalModelConfig$get_global_error_variance()`

Method `new()`:

Usage:

```
GlobalModelConfig$new(global_error_variance = 1)
```

Arguments:

global_error_variance Global error variance parameter (default: 1.0)

Returns: A new GlobalModelConfig object.

Method update_global_error_variance(): Update global error variance parameter

Usage:

```
GlobalModelConfig$update_global_error_variance(global_error_variance)
```

Arguments:

global_error_variance Global error variance parameter

Method get_global_error_variance(): Query global error variance parameter for this GlobalModelConfig object

Usage:

```
GlobalModelConfig$get_global_error_variance()
```

 JSONCreation

JSON Creation Routines

Description

The [CppJson](#) class wraps an external pointer to C++ JSON object for a seamless R serialization interface. This function group provides several utilities for creating [CppJson](#) objects: from scratch (i.e. initializing an empty JSON object), from a JSON file, or from a string that parses to valid JSON.

createCppJson creates a new (empty) [CppJson](#) object. createCppJsonFile creates and populates a [CppJson](#) object from data in a JSON file. createCppJsonString creates and populates a [CppJson](#) object from a JSON string.

These functions are intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Usage

```
createCppJson()
```

```
createCppJsonFile(json_filename)
```

```
createCppJsonString(json_string)
```

Arguments

json_filename Name of JSON file to read. Must end in .json.

json_string JSON string

Value

Each of the functions in this group returns a CppJson object.

Examples

```
example_vec <- runif(10)
example_json <- createCppJson()
example_json$add_vector("myvec", example_vec)
tmpjson <- tempfile(fileext = ".json")
example_json$save_file(file.path(tmpjson))
example_json_roundtrip <- createCppJsonFile(file.path(tmpjson))
unlink(tmpjson)
example_json_string <- example_json$return_json_string()
example_json_roundtrip <- createCppJsonString(example_json_string)
```

loadScalarJson

Load Scalar from JSON

Description

Load a scalar from json

This function is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Usage

```
loadScalarJson(json_object, json_scalar_label, subfolder_name = NULL)
```

Arguments

```
json_object      Object of class CppJson
json_scalar_label
                  Label referring to a particular scalar / string value (i.e. "num_samples") in the
                  overall json hierarchy
subfolder_name  (Optional) Name of the subfolder / hierarchy under which vector sits
```

Value

R vector

Examples

```
example_scalar <- 5.4
example_json <- createCppJson()
example_json$add_scalar("myscalar", example_scalar)
roundtrip_scalar <- loadScalarJson(example_json, "myscalar")
```

loadVectorJson	<i>Load Vector from JSON</i>
----------------	------------------------------

Description

Load a vector from json

This function is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Usage

```
loadVectorJson(json_object, json_vector_label, subfolder_name = NULL)
```

Arguments

`json_object` Object of class CppJson
`json_vector_label` Label referring to a particular vector (i.e. "sigma2_global_samples") in the overall json hierarchy
`subfolder_name` (Optional) Name of the subfolder / hierarchy under which vector sits

Value

R vector

Examples

```
example_vec <- runif(10)
example_json <- createCppJson()
example_json$add_vector("myvec", example_vec)
roundtrip_vec <- loadVectorJson(example_json, "myvec")
```

Outcome	<i>Outcome Data C++ Wrapper</i>
---------	---------------------------------

Description

Outcome / partial residual used to sample an additive model. The outcome class is a wrapper around a vector of (mutable) outcomes for ML tasks (supervised learning, causal inference). When an additive tree ensemble is sampled, the outcome used to sample a specific model term is the "partial residual" consisting of the outcome minus the predictions of every other model term (trees, group random effects, etc...).

This class is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Public fields

`data_ptr` External pointer to a C++ Outcome class

Methods

Public methods:

- `Outcome$new()`
- `Outcome$get_data()`
- `Outcome$add_vector()`
- `Outcome$subtract_vector()`
- `Outcome$update_data()`

Method `new()`: Create a new Outcome object.

Usage:

```
Outcome$new(outcome)
```

Arguments:

`outcome` Vector of outcome values

Returns: A new Outcome object.

Method `get_data()`: Extract raw data in R from the underlying C++ object

Usage:

```
Outcome$get_data()
```

Returns: R vector containing (copy of) the values in Outcome object

Method `add_vector()`: Update the current state of the outcome (i.e. partial residual) data by adding the values of `update_vector`

Usage:

```
Outcome$add_vector(update_vector)
```

Arguments:

`update_vector` Vector to be added to outcome

Returns: None

Method `subtract_vector()`: Update the current state of the outcome (i.e. partial residual) data by subtracting the values of `update_vector`

Usage:

```
Outcome$subtract_vector(update_vector)
```

Arguments:

`update_vector` Vector to be subtracted from outcome

Returns: None

Method `update_data()`: Update the current state of the outcome (i.e. partial residual) data by replacing each element with the elements of `new_vector`

Usage:

```
Outcome$update_data(new_vector)
```

Arguments:

`new_vector` Vector from which to overwrite the current data

Returns: None

OutcomeModel

Create a New Outcome Model Object

Description

Create a New Outcome Model Object

Usage

```
OutcomeModel(outcome = "continuous", link = NULL)
```

Arguments

<code>outcome</code>	Character string specifying the outcome type.
<code>link</code>	Character string specifying the link function.

Value

An object of class `outcome_model`.

Examples

```
my_model <- OutcomeModel(outcome = "continuous", link = "identity")
```

plot.bartmodel	<i>Plot BART Model Fit</i>
----------------	----------------------------

Description

Plot the BART model fit and any relevant sampled quantities. This will default to a traceplot of the global error scale and the in-sample mean forest predictions for the first train set observation. Since `stochtree::bart()` is flexible and it's possible to sample a model with a fixed global error scale and no mean forest, this procedure is adaptive and will attempt to plot a trace of whichever model terms are included if these two default terms are omitted.

Usage

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

Arguments

x	The BART model object
...	Additional arguments

Value

BART model object unchanged after summarizing

plot.bcfmodel	<i>Plot BCF Model</i>
---------------	-----------------------

Description

Plot the BCF model fit and any relevant sampled quantities. This will default to a traceplot of the global error scale and the in-sample mean forest predictions for the first train set observation. Since `stochtree::bcf()` is flexible and it's possible to sample a model with a fixed global error scale and no mean forest, this procedure will throw an error if these two default terms are omitted.

Usage

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

Arguments

x	The BCF model object
...	Additional arguments

Value

BCF model object unchanged after summarizing

predict.bartmodel *Predict from a BART Model*

Description

Predict from a sampled BART model on new data

Usage

```
## S3 method for class 'bartmodel'
predict(
  object,
  X,
  leaf_basis = NULL,
  rfx_group_ids = NULL,
  rfx_basis = NULL,
  type = "posterior",
  terms = "all",
  scale = "linear",
  ...
)
```

Arguments

object	Object of type bart containing draws of a regression forest and associated sampling outputs.
X	Covariates used to determine tree leaf predictions for each observation. Must be passed as a matrix or dataframe.
leaf_basis	(Optional) Bases used for prediction (by e.g. dot product with leaf values). Default: NULL.
rfx_group_ids	(Optional) Test set group labels used for an additive random effects model. We do not currently support (but plan to in the near future), test set evaluation for group labels that were not in the training set.
rfx_basis	(Optional) Test set basis for "random-slope" regression in additive random effects model.
type	(Optional) Type of prediction to return. Options are "mean", which averages the predictions from every draw of a BART model, and "posterior", which returns the entire matrix of posterior predictions. Default: "posterior".
terms	(Optional) Which model terms to include in the prediction. This can be a single term or a list of model terms. Options include "y_hat", "mean_forest", "rfx", "variance_forest", or "all". If a model doesn't have mean forest, random effects, or variance forest predictions, but one of those terms is request, the request will

simply be ignored. If none of the requested terms are present in a model, this function will return NULL along with a warning. Default: "all".

`scale` (Optional) Scale of mean function predictions. Options are "linear", which returns predictions on the original scale of the mean forest / RFX terms, "probability", which transforms predictions into class probabilities for models with discrete outcomes, and "class", which returns predicted outcome categories for discrete outcome models. "probability" is only valid for outcome models with `outcome == 'binary'` or `outcome == 'ordinal'`. For binary outcomes, this will return the probability that `y == 1`, and for ordinal outcomes, this will return probabilities for each outcome label. Default: "linear".

... (Optional) Other prediction parameters.

Value

List of prediction matrices or single prediction matrix / vector, depending on the terms requested.

Examples

```
n <- 100
p <- 5
X <- matrix(runif(n*p), ncol = p)
f_XW <- (
  ((0 <= X[,1]) & (0.25 > X[,1])) * (-7.5) +
  ((0.25 <= X[,1]) & (0.5 > X[,1])) * (-2.5) +
  ((0.5 <= X[,1]) & (0.75 > X[,1])) * (2.5) +
  ((0.75 <= X[,1]) & (1 > X[,1])) * (7.5)
)
noise_sd <- 1
y <- f_XW + rnorm(n, 0, noise_sd)
test_set_pct <- 0.2
n_test <- round(test_set_pct*n)
n_train <- n - n_test
test_inds <- sort(sample(1:n, n_test, replace = FALSE))
train_inds <- (1:n)[!((1:n) %in% test_inds)]
X_test <- X[test_inds,]
X_train <- X[train_inds,]
y_test <- y[test_inds]
y_train <- y[train_inds]
bart_model <- bart(X_train = X_train, y_train = y_train,
  num_gfr = 10, num_burnin = 0, num_mcmc = 10)
y_hat_test <- predict(bart_model, X=X_test)$y_hat
```

predict.bcfmodel

Predict from BCF Model

Description

Predict from a sampled BCF model on new data

Usage

```
## S3 method for class 'bcfmodel'
predict(
  object,
  X,
  Z,
  propensity = NULL,
  rfx_group_ids = NULL,
  rfx_basis = NULL,
  type = "posterior",
  terms = "all",
  scale = "linear",
  ...
)
```

Arguments

object	Object of type bcfmodel containing draws of a Bayesian causal forest model and associated sampling outputs.
X	Covariates used to determine tree leaf predictions for each observation. Must be passed as a matrix or dataframe.
Z	Treatments used for prediction.
propensity	(Optional) Propensities used for prediction.
rfx_group_ids	(Optional) Test set group labels used for an additive random effects model. We do not currently support (but plan to in the near future), test set evaluation for group labels that were not in the training set.
rfx_basis	(Optional) Test set basis for "random-slope" regression in additive random effects model. If the model was sampled with a random effects model_spec of "intercept_only" or "intercept_plus_treatment", this is optional, but if it is provided, it will be used.
type	(Optional) Type of prediction to return. Options are "mean", which averages the predictions from every draw of a BCF model, and "posterior", which returns the entire matrix of posterior predictions. Default: "posterior".
terms	(Optional) Which model terms to include in the prediction. This can be a single term or a list of model terms. Options include "y_hat", "prognostic_function", "mu", "cate", "tau", "rfx", "variance_forest", or "all". If a model doesn't have random effects or variance forest predictions, but one of those terms is request, the request will simply be ignored. If a model has random effects fit with either "intercept_only" or "intercept_plus_treatment" model_spec, then "prognostic_function" refers to the predictions of the prognostic forest plus the random intercept and "cate" refers to the predictions of the treatment effect forest plus the random slope on the treatment variable. For these models, the forest predictions alone can be requested via "mu" (prognostic forest) and "tau" (treatment effect forest). In all other cases, "mu" will return exactly the same result as "prognostic_function" and "tau" will return exactly the same result as "cate". If none of the requested terms are present in a model, this function will return NULL along with a warning. Default: "all".

scale (Optional) Scale of mean function predictions. Options are "linear", which returns predictions on the original scale of the mean forest / RFX terms, and "probability", which transforms predictions into a probability of observing $y = 1$. "probability" is only valid for models fit with a probit outcome model. Default: "linear".

... (Optional) Other prediction parameters.

Value

List of prediction matrices or single prediction matrix / vector, depending on the terms requested.

Examples

```
n <- 500
p <- 5
X <- matrix(runif(n*p), ncol = p)
mu_x <- (
  ((0 <= X[,1]) & (0.25 > X[,1])) * (-7.5) +
  ((0.25 <= X[,1]) & (0.5 > X[,1])) * (-2.5) +
  ((0.5 <= X[,1]) & (0.75 > X[,1])) * (2.5) +
  ((0.75 <= X[,1]) & (1 > X[,1])) * (7.5)
)
pi_x <- (
  ((0 <= X[,1]) & (0.25 > X[,1])) * (0.2) +
  ((0.25 <= X[,1]) & (0.5 > X[,1])) * (0.4) +
  ((0.5 <= X[,1]) & (0.75 > X[,1])) * (0.6) +
  ((0.75 <= X[,1]) & (1 > X[,1])) * (0.8)
)
tau_x <- (
  ((0 <= X[,2]) & (0.25 > X[,2])) * (0.5) +
  ((0.25 <= X[,2]) & (0.5 > X[,2])) * (1.0) +
  ((0.5 <= X[,2]) & (0.75 > X[,2])) * (1.5) +
  ((0.75 <= X[,2]) & (1 > X[,2])) * (2.0)
)
Z <- rbinom(n, 1, pi_x)
noise_sd <- 1
y <- mu_x + tau_x*Z + rnorm(n, 0, noise_sd)
test_set_pct <- 0.2
n_test <- round(test_set_pct*n)
n_train <- n - n_test
test_inds <- sort(sample(1:n, n_test, replace = FALSE))
train_inds <- (1:n)[!((1:n) %in% test_inds)]
X_test <- X[test_inds,]
X_train <- X[train_inds,]
pi_test <- pi_x[test_inds]
pi_train <- pi_x[train_inds]
Z_test <- Z[test_inds]
Z_train <- Z[train_inds]
y_test <- y[test_inds]
y_train <- y[train_inds]
mu_test <- mu_x[test_inds]
mu_train <- mu_x[train_inds]
```

```

tau_test <- tau_x[test_inds]
tau_train <- tau_x[train_inds]
bcf_model <- bcf(X_train = X_train, Z_train = Z_train, y_train = y_train,
                propensity_train = pi_train, num_gfr = 10,
                num_burnin = 0, num_mcmc = 10)
preds <- predict(bcf_model, X_test, Z_test, pi_test)

```

```
print.bartmodel
```

Print Summary of BART Model

Description

Prints a summary of the BART model, including the model terms and their specifications.

Usage

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

Arguments

```
x
```

The BART model object

```
...
```

Additional arguments

Value

BART model object unchanged after printing summary

```
print.bcfmodel
```

Print Summary of BCF Model

Description

Prints a summary of the BCF model, including the model terms and their specifications.

Usage

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

Arguments

```
x
```

The BCF model object

```
...
```

Additional arguments (currently unused)

Value

BCF model object unchanged after printing summary

```
print.ForestSamples
```

Summarize a ForestSamples Object

Description

Prints a summary of the ForestSamples object, including number of forests and the underlying model of each forest.

Usage

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

Arguments

x	ForestSamples object
...	Additional arguments

Value

ForestSamples object unchanged after printing summary

```
print.RandomEffectSamples
```

Summarize a RandomEffectSamples Object

Description

Prints a summary of the RandomEffectSamples object, including number of forests and the underlying model of each forest.

Usage

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

Arguments

x	RandomEffectSamples object
...	Additional arguments

Value

RandomEffectSamples object unchanged after printing summary

 RandomEffectSamples *Random Effect Container C++ Wrapper*

Description

Class that wraps the "persistent" aspects of a C++ random effects model, including draws of the parameters and a map from the original label indices to the 0-indexed label numbers used to place group samples in memory (i.e. the first label is stored in column 0 of the sample matrix, the second label is store in column 1 of the sample matrix, etc...)

This class is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Coordinates various C++ random effects classes and persists those needed for prediction / serialization

Public fields

`rfx_container_ptr` External pointer to a C++ `StochTree::RandomEffectsContainer` class

`label_mapper_ptr` External pointer to a C++ `StochTree::LabelMapper` class

`training_group_ids` Unique vector of group IDs that were in the training dataset

Methods

Public methods:

- `RandomEffectSamples$new()`
- `RandomEffectSamples$load_in_session()`
- `RandomEffectSamples$load_from_json()`
- `RandomEffectSamples$append_from_json()`
- `RandomEffectSamples$load_from_json_string()`
- `RandomEffectSamples$append_from_json_string()`
- `RandomEffectSamples$predict()`
- `RandomEffectSamples$extract_parameter_samples()`
- `RandomEffectSamples$delete_sample()`
- `RandomEffectSamples$extract_label_mapping()`
- `RandomEffectSamples$num_samples()`
- `RandomEffectSamples$num_components()`
- `RandomEffectSamples$num_groups()`

Method `new()`: Create a new `RandomEffectSamples` object.

Usage:

```
RandomEffectSamples$new()
```

Returns: A new `RandomEffectSamples` object.

Method `load_in_session()`: Construct `RandomEffectSamples` object from other "in-session" R objects

Usage:

```
RandomEffectSamples$load_in_session(
  num_components,
  num_groups,
  random_effects_tracker
)
```

Arguments:

`num_components` Number of "components" or bases defining the random effects regression

`num_groups` Number of random effects groups

`random_effects_tracker` Object of type `RandomEffectsTracker`

Returns: None

Method `load_from_json()`: Construct `RandomEffectSamples` object from a json object

Usage:

```
RandomEffectSamples$load_from_json(
  json_object,
  json_rfx_container_label,
  json_rfx_mapper_label,
  json_rfx_groupids_label
)
```

Arguments:

`json_object` Object of class `CppJson`

`json_rfx_container_label` Label referring to a particular rfx sample container (i.e. "random_effect_container_0") in the overall json hierarchy

`json_rfx_mapper_label` Label referring to a particular rfx label mapper (i.e. "random_effect_label_mapper_0") in the overall json hierarchy

`json_rfx_groupids_label` Label referring to a particular set of rfx group IDs (i.e. "random_effect_groupids_0") in the overall json hierarchy

Returns: A new `RandomEffectSamples` object.

Method `append_from_json()`: Append random effect draws to `RandomEffectSamples` object from a json object

Usage:

```
RandomEffectSamples$append_from_json(
  json_object,
  json_rfx_container_label,
  json_rfx_mapper_label,
  json_rfx_groupids_label
)
```

Arguments:

`json_object` Object of class `CppJson`

`json_rfx_container_label` Label referring to a particular rfx sample container (i.e. "random_effect_container_0") in the overall json hierarchy

json_rfx_mapper_label Label referring to a particular rfx label mapper (i.e. "random_effect_label_mapper_0") in the overall json hierarchy

json_rfx_groupids_label Label referring to a particular set of rfx group IDs (i.e. "random_effect_groupids_0") in the overall json hierarchy

Returns: None

Method load_from_json_string(): Construct RandomEffectSamples object from a json object

Usage:

```
RandomEffectSamples$load_from_json_string(
  json_string,
  json_rfx_container_label,
  json_rfx_mapper_label,
  json_rfx_groupids_label
)
```

Arguments:

json_string JSON string which parses into object of class CppJson

json_rfx_container_label Label referring to a particular rfx sample container (i.e. "random_effect_container_0") in the overall json hierarchy

json_rfx_mapper_label Label referring to a particular rfx label mapper (i.e. "random_effect_label_mapper_0") in the overall json hierarchy

json_rfx_groupids_label Label referring to a particular set of rfx group IDs (i.e. "random_effect_groupids_0") in the overall json hierarchy

Returns: A new RandomEffectSamples object.

Method append_from_json_string(): Append random effect draws to RandomEffectSamples object from a json object

Usage:

```
RandomEffectSamples$append_from_json_string(
  json_string,
  json_rfx_container_label,
  json_rfx_mapper_label,
  json_rfx_groupids_label
)
```

Arguments:

json_string JSON string which parses into object of class CppJson

json_rfx_container_label Label referring to a particular rfx sample container (i.e. "random_effect_container_0") in the overall json hierarchy

json_rfx_mapper_label Label referring to a particular rfx label mapper (i.e. "random_effect_label_mapper_0") in the overall json hierarchy

json_rfx_groupids_label Label referring to a particular set of rfx group IDs (i.e. "random_effect_groupids_0") in the overall json hierarchy

Returns: None

Method predict(): Predict random effects for each observation implied by rfx_group_ids and rfx_basis. If a random effects model is "intercept-only" the rfx_basis will be a vector of ones of size length(rfx_group_ids).

Usage:

```
RandomEffectSamples$predict(rfx_group_ids, rfx_basis = NULL)
```

Arguments:

rfx_group_ids Indices of random effects groups in a prediction set

rfx_basis (Optional) Basis used for random effects prediction

Returns: Matrix with as many rows as observations provided and as many columns as samples drawn of the model.

Method extract_parameter_samples(): Extract the random effects parameters sampled. With the "redundant parameterization" of Gelman et al (2008), this includes four parameters: alpha (the "working parameter" shared across every group), xi (the "group parameter" sampled separately for each group), beta (the product of alpha and xi, which corresponds to the overall group-level random effects), and sigma (group-independent prior variance for each component of xi).

Usage:

```
RandomEffectSamples$extract_parameter_samples()
```

Returns: List of arrays. The alpha array has dimension (num_components, num_samples) and is simply a vector if num_components = 1. The xi and beta arrays have dimension (num_components, num_groups, num_samples) and are simply matrices if num_components = 1. The sigma array has dimension (num_components, num_samples) and is simply a vector if num_components = 1.

Method delete_sample(): Modify the RandomEffectsSamples object by removing the parameter samples index by sample_num.

Usage:

```
RandomEffectSamples$delete_sample(sample_num)
```

Arguments:

sample_num Index of the RFX sample to be removed

Method extract_label_mapping(): Convert the mapping of group IDs to random effect components indices from C++ to R native format

Usage:

```
RandomEffectSamples$extract_label_mapping()
```

Returns: List mapping group ID to random effect components.

Method num_samples(): Query the number of samples in the RandomEffectsSamples object.

Usage:

```
RandomEffectSamples$num_samples()
```

Returns: Integer number of samples

Method num_components(): Query the number of components in the RandomEffectsSamples object.

Usage:

RandomEffectSamples\$num_components()

Returns: Integer number of components

Method num_groups(): Query the number of groups in the RandomEffectsSamples object.

Usage:

RandomEffectSamples\$num_groups()

Returns: Integer number of groups

RandomEffectSamplesSerialization

Random Effects Container Serialization Routines

Description

While the [BARTSerialization](#) and [BCFSerialization](#) topics focus on JSON serialization / deserialization for entire bartmodel and bcfmodel objects, this function group provides an interface for a more focused use case: loading a single [RandomEffectSamples](#) container from a broader BART / BCF model (which may include forests and other parametric terms).

loadRandomEffectSamplesJson converts a [CppJson](#) object representing a BART or BCF model into a [RandomEffectSamples](#) container by extracting the JSON indexed by an integer label (i.e. 0) and deserializing it into a [RandomEffectSamples](#) object.

Both loadRandomEffectSamplesJson and loadRandomEffectSamplesCombinedJson operate similarly, but on a list of [CppJson](#) or JSON string representations of BART / BCF models with the same structure.

These functions are intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Usage

```
loadRandomEffectSamplesJson(json_object, json_rfx_num)
```

```
loadRandomEffectSamplesCombinedJson(json_object_list, json_rfx_num)
```

```
loadRandomEffectSamplesCombinedJsonString(json_string_list, json_rfx_num)
```

Arguments

json_object	Object of class CppJson
json_rfx_num	Integer index indicating the position of the random effects term to be unpacked (must exist in every json object in a list if a list is provided)
json_object_list	List of objects of class CppJson
json_string_list	List of objects of class CppJson

Value

Each of the functions in this group returns a RandomEffectSamples object.

Examples

```
n <- 100
p <- 10
X <- matrix(runif(n*p), ncol = p)
rfx_group_ids <- sample(1:2, size = n, replace = TRUE)
rfx_basis <- rep(1.0, n)
y <- (-5 + 10*(X[,1] > 0.5)) + (-2*(rfx_group_ids==1)+2*(rfx_group_ids==2))
bart_model <- bart(X_train=X, y_train=y, rfx_group_ids_train=rfx_group_ids,
                  rfx_basis_train = rfx_basis, num_gfr=0, num_mcmc=10)
bart_json <- saveBARTModelToJson(bart_model)
bart_json_string <- saveBARTModelToJsonString(bart_model)
bart_json_list <- list(bart_json)
bart_json_string_list <- list(bart_json_string)
rfx_container <- loadRandomEffectSamplesJson(bart_json, 0)
rfx_container <- loadRandomEffectSamplesCombinedJson(bart_json_list, 0)
rfx_container <- loadRandomEffectSamplesCombinedJsonString(bart_json_string_list, 0)
```

RandomEffectsDataset *Random Effects Dataset C++ Wrapper*

Description

Dataset used to sample a random effects model. A random effects dataset consists of three matrices / vectors: group labels, bases, and variance weights. Variance weights are optional.

This class is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Public fields

data_ptr External pointer to a C++ RandomEffectsDataset class

Methods**Public methods:**

- [RandomEffectsDataset\\$new\(\)](#)
- [RandomEffectsDataset\\$update_basis\(\)](#)
- [RandomEffectsDataset\\$update_variance_weights\(\)](#)
- [RandomEffectsDataset\\$num_observations\(\)](#)
- [RandomEffectsDataset\\$num_basis\(\)](#)
- [RandomEffectsDataset\\$get_group_labels\(\)](#)

- `RandomEffectsDataset$get_basis()`
- `RandomEffectsDataset$get_variance_weights()`
- `RandomEffectsDataset$has_group_labels()`
- `RandomEffectsDataset$has_basis()`
- `RandomEffectsDataset$has_variance_weights()`

Method `new()`: Create a new `RandomEffectsDataset` object.

Usage:

```
RandomEffectsDataset$new(group_labels, basis, variance_weights = NULL)
```

Arguments:

`group_labels` Vector of group labels

`basis` Matrix of bases used to define the random effects regression (for an intercept-only model, pass an array of ones)

`variance_weights` (Optional) Vector of observation-specific variance weights

Returns: A new `RandomEffectsDataset` object.

Method `update_basis()`: Update basis matrix in a dataset

Usage:

```
RandomEffectsDataset$update_basis(basis)
```

Arguments:

`basis` Updated matrix of bases used to define random slopes / intercepts

Method `update_variance_weights()`: Update `variance_weights` in a dataset

Usage:

```
RandomEffectsDataset$update_variance_weights(
  variance_weights,
  exponentiate = F
)
```

Arguments:

`variance_weights` Updated vector of variance weights used to define individual variance / case weights

`exponentiate` Whether or not input vector should be exponentiated before being written to the `RandomEffectsDataset`'s variance weights. Default: F.

Method `num_observations()`: Return number of observations in a `RandomEffectsDataset` object

Usage:

```
RandomEffectsDataset$num_observations()
```

Returns: Observation count

Method `num_basis()`: Return dimension of the basis matrix in a `RandomEffectsDataset` object

Usage:

```
RandomEffectsDataset$num_basis()
```

Returns: Basis vector count

Method `get_group_labels()`: Return group labels as an R vector

Usage:

`RandomEffectsDataset$get_group_labels()`

Returns: Group label data

Method `get_basis()`: Return bases as an R matrix

Usage:

`RandomEffectsDataset$get_basis()`

Returns: Basis data

Method `get_variance_weights()`: Return variance weights as an R vector

Usage:

`RandomEffectsDataset$get_variance_weights()`

Returns: Variance weight data

Method `has_group_labels()`: Whether or not a dataset has group label indices

Usage:

`RandomEffectsDataset$has_group_labels()`

Returns: True if group label vector is loaded, false otherwise

Method `has_basis()`: Whether or not a dataset has a basis matrix

Usage:

`RandomEffectsDataset$has_basis()`

Returns: True if basis matrix is loaded, false otherwise

Method `has_variance_weights()`: Whether or not a dataset has variance weights

Usage:

`RandomEffectsDataset$has_variance_weights()`

Returns: True if variance weights are loaded, false otherwise

RandomEffectsModel *Random Effects Model C++ Wrapper*

Description

The core "model" class for sampling random effects. Stores current model state, prior parameters, and procedures for sampling from the conditional posterior of each parameter.

This class is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Public fields

`rfx_model_ptr` External pointer to a C++ `StochTree::RandomEffectsModel` class
`num_groups` Number of groups in the random effects model
`num_components` Number of components (i.e. dimension of basis) in the random effects model

Methods**Public methods:**

- `RandomEffectsModel$new()`
- `RandomEffectsModel$sample_random_effect()`
- `RandomEffectsModel$predict()`
- `RandomEffectsModel$set_working_parameter()`
- `RandomEffectsModel$set_group_parameters()`
- `RandomEffectsModel$set_working_parameter_cov()`
- `RandomEffectsModel$set_group_parameter_cov()`
- `RandomEffectsModel$set_variance_prior_shape()`
- `RandomEffectsModel$set_variance_prior_scale()`

Method `new()`: Create a new `RandomEffectsModel` object.

Usage:

```
RandomEffectsModel$new(num_components, num_groups)
```

Arguments:

`num_components` Number of "components" or bases defining the random effects regression
`num_groups` Number of random effects groups

Returns: A new `RandomEffectsModel` object.

Method `sample_random_effect()`: Sample from random effects model.

Usage:

```
RandomEffectsModel$sample_random_effect(
  rfx_dataset,
  residual,
  rfx_tracker,
  rfx_samples,
  keep_sample,
  global_variance,
  rng
)
```

Arguments:

`rfx_dataset` Object of type `RandomEffectsDataset`
`residual` Object of type `Outcome`
`rfx_tracker` Object of type `RandomEffectsTracker`
`rfx_samples` Object of type `RandomEffectSamples`

`keep_sample` Whether sample should be retained in `rfx_samples`. If `FALSE`, the state of `rfx_tracker` will be updated, but the parameter values will not be added to the sample container. Samples are commonly discarded due to burn-in or thinning.

`global_variance` Scalar global variance parameter

`rng` Object of type `CppRNG`

Returns: None

Method `predict()`: Predict from (a single sample of a) random effects model.

Usage:

```
RandomEffectsModel$predict(rfx_dataset, rfx_tracker)
```

Arguments:

`rfx_dataset` Object of type `RandomEffectsDataset`

`rfx_tracker` Object of type `RandomEffectsTracker`

Returns: Vector of predictions with size matching number of observations in `rfx_dataset`

Method `set_working_parameter()`: Set value for the "working parameter." This is typically used for initialization, but could also be used to interrupt or override the sampler.

Usage:

```
RandomEffectsModel$set_working_parameter(value)
```

Arguments:

`value` Parameter input

Returns: None

Method `set_group_parameters()`: Set value for the "group parameters." This is typically used for initialization, but could also be used to interrupt or override the sampler.

Usage:

```
RandomEffectsModel$set_group_parameters(value)
```

Arguments:

`value` Parameter input

Returns: None

Method `set_working_parameter_cov()`: Set value for the working parameter covariance. This is typically used for initialization, but could also be used to interrupt or override the sampler.

Usage:

```
RandomEffectsModel$set_working_parameter_cov(value)
```

Arguments:

`value` Parameter input

Returns: None

Method `set_group_parameter_cov()`: Set value for the group parameter covariance. This is typically used for initialization, but could also be used to interrupt or override the sampler.

Usage:

RandomEffectsModel\$set_group_parameter_cov(value)

Arguments:

value Parameter input

Returns: None

Method set_variance_prior_shape(): Set shape parameter for the group parameter variance prior.

Usage:

RandomEffectsModel\$set_variance_prior_shape(value)

Arguments:

value Parameter input

Returns: None

Method set_variance_prior_scale(): Set shape parameter for the group parameter variance prior.

Usage:

RandomEffectsModel\$set_variance_prior_scale(value)

Arguments:

value Parameter input

Returns: None

RandomEffectStateManagement

Random Effects State Management Routines

Description

A forest sampler features two types of state: ephemeral and persistent. Persistent state includes objects like [ForestSamples](#) and [RandomEffectSamples](#) which constitute part of the final sampled model. Ephemeral state supports the sampling computations, but is not retained after the sampler finishes.

The two primary random-effects-based bits of ephemeral state are the [RandomEffectsModel](#) and [RandomEffectsTracker](#) classes, which represent the current state of a random effects model and its corresponding tracking data structures.

In a linear sampling loop, this ephemeral state is updated with each iteration of the sampler and any retained forests are copied to a [RandomEffectSamples](#) object. However, in multi-chain settings, the state of a random effects model must typically be "reset" at the beginning of a new chain. These function enable this process by synchronizing the state of a [RandomEffectsModel](#) and [RandomEffectsTracker](#) with a corresponding element of a [RandomEffectSamples](#) object, or by resetting both to their default (root) state.

resetRandomEffectsModel resets a RandomEffectsModel object based on the parameters indexed by sample_num in a RandomEffectSamples object. resetRandomEffectsTracker resets a

RandomEffectsTracker object based on the parameters indexed by `sample_num` in a RandomEffectsSamples object.

`rootResetRandomEffectsModel` resets a RandomEffectsModel object to its "default" state. `rootResetRandomEffectsTracker` resets a RandomEffectsTracker object to its "default" state.

These functions are intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Usage

```
resetRandomEffectsModel(rfx_model, rfx_samples, sample_num, sigma_alpha_init)
```

```
resetRandomEffectsTracker(
  rfx_tracker,
  rfx_model,
  rfx_dataset,
  residual,
  rfx_samples
)
```

```
rootResetRandomEffectsModel(
  rfx_model,
  alpha_init,
  xi_init,
  sigma_alpha_init,
  sigma_xi_init,
  sigma_xi_shape,
  sigma_xi_scale
)
```

```
rootResetRandomEffectsTracker(rfx_tracker, rfx_model, rfx_dataset, residual)
```

Arguments

<code>rfx_model</code>	Object of type RandomEffectsModel.
<code>rfx_samples</code>	Object of type RandomEffectSamples.
<code>sample_num</code>	Index of sample stored in <code>rfx_samples</code> from which to reset the state of a random effects model. Zero-indexed, so resetting based on the first sample would require setting <code>sample_num = 0</code> .
<code>sigma_alpha_init</code>	Initial value of the "working parameter" scale parameter.
<code>rfx_tracker</code>	Object of type RandomEffectsTracker.
<code>rfx_dataset</code>	Object of type RandomEffectsDataset.
<code>residual</code>	Object of type Outcome.
<code>alpha_init</code>	Initial value of the "working parameter".

`xi_init` Initial value of the "group parameters".
`sigma_xi_init` Initial value of the "group parameters" scale parameter.
`sigma_xi_shape` Shape parameter for the inverse gamma variance model on the group parameters.
`sigma_xi_scale` Scale parameter for the inverse gamma variance model on the group parameters.

Value

All four functions have no return type and operate in-place on the relevant [RandomEffectsModel](#) or [RandomEffectsTracker](#) objects

Examples

```

n <- 100
p <- 10
rfx_group_ids <- sample(1:2, size = n, replace = TRUE)
rfx_basis <- matrix(rep(1.0, n), ncol=1)
rfx_dataset <- createRandomEffectsDataset(rfx_group_ids, rfx_basis)
y <- (-2*(rfx_group_ids==1)+2*(rfx_group_ids==2)) + rnorm(n)
y_std <- (y-mean(y))/sd(y)
outcome <- createOutcome(y_std)
rng <- createCppRNG(1234)
num_groups <- length(unique(rfx_group_ids))
num_components <- ncol(rfx_basis)
rfx_model <- createRandomEffectsModel(num_components, num_groups)
rfx_tracker <- createRandomEffectsTracker(rfx_group_ids)
rfx_samples <- createRandomEffectSamples(num_components, num_groups, rfx_tracker)
alpha_init <- rep(1,num_components)
xi_init <- matrix(rep(alpha_init, num_groups),num_components,num_groups)
sigma_alpha_init <- diag(1,num_components,num_components)
sigma_xi_init <- diag(1,num_components,num_components)
sigma_xi_shape <- 1
sigma_xi_scale <- 1
rfx_model$set_working_parameter(alpha_init)
rfx_model$set_group_parameters(xi_init)
rfx_model$set_working_parameter_cov(sigma_alpha_init)
rfx_model$set_group_parameter_cov(sigma_xi_init)
rfx_model$set_variance_prior_shape(sigma_xi_shape)
rfx_model$set_variance_prior_scale(sigma_xi_scale)
for (i in 1:3) {
  rfx_model$sample_random_effect(rfx_dataset=rfx_dataset, residual=outcome,
                                rfx_tracker=rfx_tracker, rfx_samples=rfx_samples,
                                keep_sample=TRUE, global_variance=1.0, rng=rng)
}
resetRandomEffectsModel(rfx_model, rfx_samples, 0, 1.0)
resetRandomEffectsTracker(rfx_tracker, rfx_model, rfx_dataset, outcome, rfx_samples)
rootResetRandomEffectsModel(rfx_model, alpha_init, xi_init, sigma_alpha_init,
                             sigma_xi_init, sigma_xi_shape, sigma_xi_scale)
rootResetRandomEffectsTracker(rfx_tracker, rfx_model, rfx_dataset, outcome)
  
```

RandomEffectsTracker *Random Effects Tracker C++ Wrapper*

Description

Class that defines a "tracker" for random effects models, most notably storing the data indices available in each group for quicker posterior computation and sampling of random effects terms. The class stores a mapping from every observation to its group index, a mapping from group indices to the training sample observations available in that group, and predictions for each observation.

This class is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Public fields

rfx_tracker_ptr External pointer to a C++ StochTree::RandomEffectsTracker class

Methods

Public methods:

- [RandomEffectsTracker\\$new\(\)](#)

Method `new()`: Create a new RandomEffectsTracker object.

Usage:

`RandomEffectsTracker$new(rfx_group_indices)`

Arguments:

`rfx_group_indices` Integer indices indicating groups used to define random effects

Returns: A new RandomEffectsTracker object.

sampleBARTPosteriorPredictive

Sample BART Posterior Predictive

Description

Sample from the posterior predictive distribution for outcomes modeled by BART

Usage

```
sampleBARTPosteriorPredictive(
  model_object,
  X = NULL,
  leaf_basis = NULL,
  rfx_group_ids = NULL,
  rfx_basis = NULL,
  num_draws_per_sample = NULL
)
```

Arguments

<code>model_object</code>	A fitted BART model object of class <code>bartmodel</code> .
<code>X</code>	A matrix or data frame of covariates. Required if the BART model depends on covariates (e.g., contains a mean or variance forest).
<code>leaf_basis</code>	A matrix of bases for mean forest models with regression defined in the leaves. Required for "leaf regression" models.
<code>rfx_group_ids</code>	A vector of group IDs for random effects model. Required if the BART model includes random effects.
<code>rfx_basis</code>	A matrix of bases for random effects model. Required if the BART model includes random effects.
<code>num_draws_per_sample</code>	The number of posterior predictive samples to draw for each posterior sample. Defaults to a heuristic based on the number of samples in a BART model (i.e. if the BART model has >1000 draws, we use 1 draw from the likelihood per sample, otherwise we upsample to ensure intervals are based on at least 1000 posterior predictive draws).

Value

Array of posterior predictive samples with dimensions `(num_observations, num_posterior_samples, num_draws_per_sample)` if `num_draws_per_sample > 1`, otherwise `(num_observations, num_posterior_samples)`.

Examples

```
n <- 100
p <- 5
X <- matrix(rnorm(n * p), nrow = n, ncol = p)
y <- 2 * X[,1] + rnorm(n)
bart_model <- bart(y_train = y, X_train = X)
ppd_samples <- sampleBARTPosteriorPredictive(
  model_object = bart_model, X = X
)
```

```
sampleBCFPosteriorPredictive
      Sample BCF Posterior Predictive
```

Description

Sample from the posterior predictive distribution for outcomes modeled by BCF

Usage

```
sampleBCFPosteriorPredictive(
  model_object,
  X = NULL,
  Z = NULL,
  propensity = NULL,
  rfx_group_ids = NULL,
  rfx_basis = NULL,
  num_draws_per_sample = NULL
)
```

Arguments

model_object	A fitted BCF model object of class <code>bcfmodel</code> .
X	A matrix or data frame of covariates.
Z	A vector or matrix of treatment assignments.
propensity	(Optional) A vector or matrix of propensity scores. Required if the underlying model depends on user-provided propensities.
rfx_group_ids	(Optional) A vector of group IDs for random effects model. Required if the BCF model includes random effects.
rfx_basis	(Optional) A matrix of bases for random effects model. Required if the BCF model includes random effects.
num_draws_per_sample	(Optional) The number of samples to draw from the likelihood for each draw of the posterior. Defaults to a heuristic based on the number of samples in a BCF model (i.e. if the BCF model has >1000 draws, we use 1 draw from the likelihood per sample, otherwise we upsample to ensure at least 1000 posterior predictive draws).

Value

Array of posterior predictive samples with dimensions `(num_observations, num_posterior_samples, num_draws_per_sample)` if `num_draws_per_sample > 1`, otherwise `(num_observations, num_posterior_samples)`.

Examples

```

n <- 100
p <- 5
X <- matrix(rnorm(n * p), nrow = n, ncol = p)
pi_X <- pnorm(X[,1] / 2)
Z <- rbinom(n, 1, pi_X)
y <- 2 * X[,2] + 0.5 * X[,2] * Z + rnorm(n)
bcf_model <- bcf(X_train = X, Z_train = Z, y_train = y, propensity_train = pi_X)
ppd_samples <- sampleBCFPosteriorPredictive(
  model_object = bcf_model, X = X,
  Z = Z, propensity = pi_X
)

```

```

sampleGlobalErrorVarianceOneIteration
Sample Global Error Variance

```

Description

Sample one iteration of the (inverse gamma) global variance model

This function is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Usage

```
sampleGlobalErrorVarianceOneIteration(residual, dataset, rng, a, b)
```

Arguments

residual	Outcome class
dataset	ForestDataset class
rng	C++ random number generator
a	Global variance shape parameter
b	Global variance scale parameter

Value

None

Examples

```
X <- matrix(runif(10*100), ncol = 10)
y <- -5 + 10*(X[,1] > 0.5) + rnorm(100)
y_std <- (y-mean(y))/sd(y)
forest_dataset <- createForestDataset(X)
outcome <- createOutcome(y_std)
rng <- createCppRNG(1234)
a <- 1.0
b <- 1.0
sigma2 <- sampleGlobalErrorVarianceOneIteration(outcome, forest_dataset, rng, a, b)
```

sampleLeafVarianceOneIteration
Sample Leaf Scale

Description

Sample one iteration of the leaf parameter variance model (only for univariate basis and constant leaf!)

This function is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the stochtree's advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Usage

```
sampleLeafVarianceOneIteration(forest, rng, a, b)
```

Arguments

forest	C++ forest
rng	C++ random number generator
a	Leaf variance shape parameter
b	Leaf variance scale parameter

Value

None

Examples

```
num_trees <- 100
leaf_dimension <- 1
is_leaf_constant <- TRUE
is_exponentiated <- FALSE
active_forest <- createForest(num_trees, leaf_dimension, is_leaf_constant, is_exponentiated)
rng <- createCppRNG(1234)
```

```
a <- 1.0
b <- 1.0
tau <- sampleLeafVarianceOneIteration(active_forest, rng, a, b)
```

sample_without_replacement

Sample Without Replacement

Description

Draw `sample_size` samples from `population_vector` without replacement, weighted by `sampling_probabilities`

This function is intended for advanced use cases in which users require detailed control of sampling algorithms and data structures. Minimal input validation and error checks are performed – users are responsible for providing the correct inputs. For tutorials on the "proper" usage of the `stochtree`'s advanced workflow, we provide several vignettes at <https://stochtree.ai/>

Usage

```
sample_without_replacement(  
  population_vector,  
  sampling_probabilities,  
  sample_size  
)
```

Arguments

`population_vector` Vector from which to draw samples.

`sampling_probabilities` Vector of probabilities of drawing each element of `population_vector`.

`sample_size` Number of samples to draw from `population_vector`. Must be less than or equal to `length(population_vector)`

Value

Vector of size `sample_size`

Examples

```
a <- as.integer(c(4,3,2,5,1,9,7))
p <- c(0.7,0.2,0.05,0.02,0.01,0.01,0.01)
num_samples <- 5
sample_without_replacement(a, p, num_samples)
```

summary.bartmodel	<i>Summarize BART Model Fit and Parameters</i>
-------------------	--

Description

Summarize a BART fit with a description of the model that was fit and numeric summaries of any sampled quantities.

Usage

```
## S3 method for class 'bartmodel'  
summary(object, ...)
```

Arguments

object	The BART model object
...	Additional arguments

Value

BART model object unchanged after summarizing

summary.bcfmodel	<i>Summarize BCF Model</i>
------------------	----------------------------

Description

Summarize a BCF fit with a description of the model that was fit and numeric summaries of any sampled quantities.

Usage

```
## S3 method for class 'bcfmodel'  
summary(object, ...)
```

Arguments

object	The BCF model object
...	Additional arguments

Value

BCF model object unchanged after summarizing

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