Package ‘diversityForest’

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Type Package
Title Innovative Complex Split Procedures in Random Forests Through Candidate Split Sampling
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Description Implements interaction forests [1], which are specific diversity forests and the basic form of diversity forests that uses univariable, binary splitting [2]. Interaction forests (IFs) are ensembles of decision trees that model quantitative and qualitative interaction effects using bivariable splitting. IFs come with the Effect Importance Measure (EIM), which can be used to identify variable pairs that feature quantitative and qualitative interaction effects with high predictive relevance. IFs and EIM focus on well interpretable forms of interactions. The package also offers plot functions for visualising the estimated forms of interaction effects. Categorical, metric, and survival outcomes are supported. This is a fork of the R package ‘ranger’ (main author: Marvin N. Wright) that implements random forests using an efficient C++ implementation.

References:

SystemRequirements C++11
Encoding UTF-8
License GPL-3
Imports Rcpp (>= 0.11.2), Matrix, ggplot2, ggpubr, scales, nnet, sgeostat, rms, MapGAM, gam, rlang, grDevices, RColorBrewer, RcppEigen, survival
LinkingTo Rcpp, RcppEigen
Diversity Forests

Description

The diversity forest algorithm is not a specific algorithm, but an alternative candidate split sampling scheme that makes complex split procedures in random forests possible computationally by drastically reducing the numbers of candidate splits that need to be evaluated for each split. It also avoids the well-known variable selection bias in conventional random forests that has the effect that variables with many possible splits are selected too frequently for splitting (Strobl et al., 2007). For details, see Hornung (2022).

Details

This package currently features two types of diversity forests:

- the basic form of diversity forests that uses univariable, binary splitting, which is also used in conventional random forests
• interaction forests (IFs) (Hornung & Boulesteix, 2022), which use bivariable splitting to model quantitative and qualitative interaction effects. IFs feature the Effect Importance Measure (EIM), which ranks the variable pairs with respect to the predictive importance of their quantitative and qualitative interaction effects. The individual variables can be ranked as well using EIM. For details, see Hornung & Boulesteix (2022).

Diversity forests with univariable splitting can be constructed using the function `divfor` and interaction forests using the function `interactionfor`. Both functions support categorical, metric, and survival outcomes.

This package is a fork of the R package 'ranger' that implements random forests using an efficient C++ implementation. The documentation is in large parts taken from 'ranger', where some parts of the documentation may not apply to (the current version of) the 'diversityForest' package.

Details on further functionalities of the code that are not presented in the help pages of 'diversityForest' are found in the help pages of 'ranger', version 0.11.0, because 'diversityForest' is based on the latter version of 'ranger'. The code in the example sections can be used as a template for all basic application scenarios with respect to classification, regression and survival prediction.

References


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`divfor`  
*Construct a basic diversity forest prediction rule that uses univariable, binary splitting.*

**Description**

Implements the most basic form of diversity forests that uses univariable, binary splitting. Currently, categorical, metric, and survival outcomes are supported.
Usage

divfor(
    formula = NULL,
    data = NULL,
    num.trees = 500,
    mtry = NULL,
    importance = "none",
    write.forest = TRUE,
    probability = FALSE,
    min.node.size = NULL,
    max.depth = NULL,
    replace = TRUE,
    sample.fraction = ifelse(replace, 1, 0.632),
    case.weights = NULL,
    class.weights = NULL,
    splitrule = NULL,
    num.random.splits = 1,
    alpha = 0.5,
    minprop = 0.1,
    split.select.weights = NULL,
    always.split.variables = NULL,
    respect.unordered.factors = NULL,
    scale.permutation.importance = FALSE,
    keep.inbag = FALSE,
    inbag = NULL,
    holdout = FALSE,
    quantreg = FALSE,
    oob.error = TRUE,
    num.threads = NULL,
    save.memory = FALSE,
    verbose = TRUE,
    seed = NULL,
    dependent.variable.name = NULL,
    status.variable.name = NULL,
    classification = NULL,
    nsplits = 30,
    proptry = 1
)

Arguments

formula Object of class formula or character describing the model to fit. Interaction
terms supported only for numerical variables.

data Training data of class data.frame, matrix, dgCMatrix (Matrix) or gwaa.data
(GenABEL).

num.trees Number of trees. Default is 500.

mtry Artefact from 'ranger'. NOT needed for diversity forests.
importance

Variable importance mode, one of 'none', 'impurity', 'impurity_corrected', 'permutation'. The 'impurity' measure is the Gini index for classification, the variance of the responses for regression and the sum of test statistics (see splitrule) for survival. NOTE: Currently, only "permutation" (and "none") work for diversity forests.

write.forest

Save divfor.forest object, required for prediction. Set to FALSE to reduce memory usage if no prediction intended.

probability

Grow a probability forest as in Malley et al. (2012). NOTE: Not yet implemented for diversity forests!

min.node.size

Minimal node size. Default 1 for classification, 5 for regression, 3 for survival, and 5 for probability.

max.depth

Maximal tree depth. A value of NULL or 0 (the default) corresponds to unlimited depth, 1 to tree stumps (1 split per tree).

replace

Sample with replacement.

case.weights

Weights for sampling of training observations. Observations with larger weights will be selected with higher probability in the bootstrap (or subsampled) samples for the trees.

class.weights

Weights for the outcome classes (in order of the factor levels) in the splitting rule (cost sensitive learning). Classification and probability prediction only. For classification the weights are also applied in the majority vote in terminal nodes.

splitrule

Splitting rule. For classification and probability estimation "gini" or "extratrees" with default "gini". For regression "variance", "extratrees" or "maxstat" with default "variance". For survival "logrank", "extratrees", "C" or "maxstat" with default "logrank". NOTE: For diversity forests currently only the default splitting rules are supported.

num.random.splits

Artefact from 'ranger'. NOT needed for diversity forests.

alpha

For "maxstat" splitrule: Significance threshold to allow splitting. NOT needed for diversity forests.

minprop

For "maxstat" splitrule: Lower quantile of covariate distribution to be considered for splitting. NOT needed for diversity forests.

split.select.weights

Numeric vector with weights between 0 and 1, representing the probability to select variables for splitting. Alternatively, a list of size num.trees, containing split select weight vectors for each tree can be used.

always.split.variables

Currently not useable. Character vector with variable names to be always selected.

respect.unordered.factors

Handling of unordered factor covariates. One of 'ignore' and 'order' (the option 'partition' possible in 'ranger' is not (yet) possible with diversity forests). Default is 'ignore'. Alternatively TRUE (="order") or FALSE (="ignore") can be used.
scale.permutation.importance

Scale permutation importance by standard error as in (Breiman 2001). Only applicable if permutation variable importance mode selected.

keep.inbag

Save how often observations are in-bag in each tree.

inbag

Manually set observations per tree. List of size num.trees, containing inbag counts for each observation. Can be used for stratified sampling.

holdout

Hold-out mode. Hold-out all samples with case weight 0 and use these for variable importance and prediction error.

quantreg

Prepare quantile prediction as in quantile regression forests (Meinshausen 2006). Regression only. Set keep.inbag = TRUE to prepare out-of-bag quantile prediction.

oob.error

Compute OOB prediction error. Set to FALSE to save computation time, e.g. for large survival forests.

num.threads

Number of threads. Default is number of CPUs available.

save.memory

Use memory saving (but slower) splitting mode. No effect for survival and GWAS data. Warning: This option slows down the tree growing, use only if you encounter memory problems. NOT needed for diversity forests.

verbose

Show computation status and estimated runtime.

seed

Random seed. Default is NULL, which generates the seed from R. Set to 0 to ignore the R seed.

dependent.variable.name

Name of outcome variable, needed if no formula given. For survival forests this is the time variable.

status.variable.name

Name of status variable, only applicable to survival data and needed if no formula given. Use 1 for event and 0 for censoring.

classification

Only needed if data is a matrix. Set to TRUE to grow a classification forest.

nsplits

Number of candidate splits to sample for each split. Default is 30.

proptry

Parameter that restricts the number of candidate splits considered for small nodes. If nsplits is larger than proptry times the number of all possible splits, the number of candidate splits to draw is reduced to the largest integer smaller than proptry times the number of all possible splits. Default is 1, which corresponds to always using nsplits candidate splits.

Value

Object of class divfor with elements

forest

Saved forest (If write.forest set to TRUE). Note that the variable IDs in the split.varIDs object do not necessarily represent the column number in R.

predictions

Predicted classes/values, based on out-of-bag samples (classification and regression only).

variable.importance

Variable importance for each independent variable.
prediction.error
Overall out-of-bag prediction error. For classification this is the fraction of misclassified samples, for probability estimation the Brier score, for regression the mean squared error and for survival one minus Harrell’s C-index.

r.squared
R squared. Also called explained variance or coefficient of determination (regression only). Computed on out-of-bag data.

confusion.matrix
Contingency table for classes and predictions based on out-of-bag samples (classification only).

unique.death.times
Unique death times (survival only).

chf
Estimated cumulative hazard function for each sample (survival only).

survival
Estimated survival function for each sample (survival only).

call
Function call.

num.trees
Number of trees.

num.independent.variables
Number of independent variables.

min.node.size
Value of minimal node size used.

treetype
Type of forest/tree. classification, regression or survival.

importance.mode
Importance mode used.

num.samples
Number of samples.

splitrule
Splitting rule.

replace
Sample with replacement.

nsplits
Value of nsplits used.

proptry
Value of proptry used.

Author(s)
Roman Hornung, Marvin N. Wright

References
See Also

predict.divfor

Examples

## Not run:
## Load package:
library("diversityForest")
## Set seed to obtain reproducible results:
set.seed(1234)

## Diversity forest with default settings (NOT recommended)
# Classification:
divfor(Species ~ ., data = iris, num.trees = 20)
# Regression:
iris2 <- iris; iris2$Species <- NULL; iris2$Y <- rnorm(nrow(iris2))
divfor(Y ~ ., data = iris2, num.trees = 20)
# Survival:
library("survival")
divfor(Surv(time, status) ~ ., data = veteran, num.trees = 20, respect.unordered.factors = "order")
# NOTE: num.trees = 20 is specified too small for practical purposes - the prediction performance of the resulting
# forest will be suboptimal!!
# In practice, num.trees = 500 (default value) or a
# larger number should be used.

## Diversity forest with specified values for nsplits and proptry (NOT recommended)
divfor(Species ~ ., data = iris, nsplits = 10, proptry = 0.4, num.trees = 20)
# NOTE again: num.trees = 20 is specified too small for practical purposes.

## Applying diversity forest after optimizing the values of nsplits and proptry (recommended)
tuneres <- tunedivfor(formula = Species ~ ., data = iris, num.trees.pre = 20)
# NOTE again: num.trees.pre = 20 is specified too small for practical purposes.
# purposes - the out-of-bag error estimates of the forests
# constructed during optimization will be much too variable!!
# In practice, num.trees.pre = 500 (default value) or a
# larger number should be used.
divfor(Species ~ ., data = iris, nsplits = tuneres$nsplitsopt,
      proptry = tuneres$proptryopt, num.trees = 20)
# NOTE again: num.trees = 20 is specified too small for practical purposes.

## Prediction
train.idx <- sample(nrow(iris), 2/3 * nrow(iris))
iris.train <- iris[train.idx, ]
iris.test <- iris[-train.idx, ]
tuneres <- tunedivfor(formula = Species ~ ., data = iris.train, num.trees.pre = 20)
# NOTE again: num.trees.pre = 20 is specified too small for practical purposes.
rg.iris <- divfor(Species ~ ., data = iris.train, nsplits = tuneres$nsplitsopt,
                  proptry = tuneres$proptryopt, num.trees = 20)
# NOTE again: num.trees = 20 is specified too small for practical purposes.
pred.iris <- predict(rg.iris, data = iris.test)
table(iris.test$Species, pred.iris$predictions)

## Variable importance
rg.iris <- divfor(Species ~ ., data = iris, importance = "permutation", num.trees = 20)
# NOTE again: num.trees = 20 is specified too small for practical purposes.
rg.iris$variable.importance

## End(Not run)

---

importance.divfor

*Diversity Forest variable importance*

**Description**

Extract variable importance of `divfor` object.

**Usage**

```r
## S3 method for class 'divfor'
importance(x, ...)
```

**Arguments**

- `x` : `divfor` object.
- `...` : Further arguments passed to or from other methods.

**Value**

Variable importance measures.

**Author(s)**

Marvin N. Wright

**See Also**

- `divfor`
interactionfor

Construct an interaction forest prediction rule and calculate EIM values as described in Hornung & Boulesteix (2022).

Description

Implements interaction forests as described in Hornung & Boulesteix (2022). Currently, categorical, metric, and survival outcomes are supported. Interaction forests feature the effect importance measure (EIM), which can be used to rank the covariate variable pairs with respect to the impact of their interaction effects on prediction. This allows to identify relevant interaction effects. Interaction forests focus on well interpretable interaction effects. See the 'Details' section below for more details.

Usage

interactionfor(
    formula = NULL,
    data = NULL,
    importance = "both",
    num.trees = NULL,
    simplify.large.n = TRUE,
    num.trees.eim.large.n = NULL,
    write.forest = TRUE,
    probability = FALSE,
    min.node.size = NULL,
    max.depth = NULL,
    replace = FALSE,
    sample.fraction = ifelse(replace, 1, 0.7),
    case.weights = NULL,
    class.weights = NULL,
    splitrule = NULL,
    always.split.variables = NULL,
    keep.inbag = FALSE,
    inbag = NULL,
    holdout = FALSE,
    quantreg = FALSE,
    oob.error = TRUE,
    num.threads = NULL,
    verbose = TRUE,
    seed = NULL,
    dependent.variable.name = NULL,
    status.variable.name = NULL,
    npairs = NULL,
    classification = NULL
)
interactionfor

Arguments

formula Object of class formula or character describing the model to fit.
data Training data of class data.frame, matrix, dgCMatrix (Matrix) or gwaa.data (GenABEL).
importance Effect importance mode. One of the following: "both" (the default), "qualitative", "quantitative", "mainonly", "none". See the 'Details' section below for explanation.
num.trees Number of trees. The default number is 20000, if EIM values should be computed and 2000 otherwise. Note that if simplify.large.n = TRUE (default), the number of observations is larger than 1000, and EIM values should be calculated two forests are constructed, one for calculating the EIM values and one for prediction (cf. 'Details' section). In such cases, the default number of trees used for the forest for EIM value calculation is 20000 and the default number of trees used for the forest for prediction is 2000.
simplify.large.n Should restricted tree depths be used, when calculating EIM values for large data sets? See the 'Details' section below for more information. Default is TRUE.
num.trees.eim.large.n Number of trees in the forest used for calculating the EIM values for large data sets. If num.trees is provided, but not num.trees.eim.large.n, the value given by num.trees will be used. The default number is 20000. Only used when simplify.large.n = TRUE.
write.forest Save interaction.forest object, required for prediction. Set to FALSE to reduce memory usage if no prediction intended.
probability Grow a probability forest as in Malley et al. (2012).
min.node.size Minimal node size. Default 1 for classification, 5 for regression, 3 for survival, and 5 for probability.
max.depth Maximal tree depth. A value of NULL or 0 (the default) corresponds to unlimited depth, 1 to tree stumps (1 split per tree).
replace Sample with replacement. Default is FALSE.
sample.fraction Fraction of observations to sample. Default is 1 for sampling with replacement and 0.7 for sampling without replacement. For classification, this can be a vector of class-specific values.
case.weights Weights for sampling of training observations. Observations with larger weights will be selected with higher probability in the bootstrap (or subsampled) samples for the trees.
class.weights Weights for the outcome classes (in order of the factor levels) in the splitting rule (cost sensitive learning). Classification and probability prediction only. For classification the weights are also applied in the majority vote in terminal nodes.
splitrule Splitting rule. For classification and probability estimation "gini" or "extratrees" with default "gini". For regression "variance", "extratrees" or "maxstat" with default "variance". For survival "logrank", "extratrees", "C" or "maxstat" with default "logrank". NOTE: For interaction forests currently only the default splitting rules are supported.
always.split.variables
Currently not useable. Character vector with variable names to be always selected.

keep.inbag
Save how often observations are in-bag in each tree.

inbag
Manually set observations per tree. List of size num.trees, containing inbag counts for each observation. Can be used for stratified sampling.

holdout
Hold-out mode. Hold-out all samples with case weight 0 and use these for variable importance and prediction error. NOTE: Currently, not useable for interaction forests.

quantreg
Prepare quantile prediction as in quantile regression forests (Meinshausen 2006). Regression only. Set keep.inbag = TRUE to prepare out-of-bag quantile prediction. NOTE: Currently, not useable for interaction forests.

oob.error
Compute OOB prediction error. Set to FALSE to save computation time, e.g. for large survival forests.

num.threads
Number of threads. Default is number of CPUs available.

verbose
Show computation status and estimated runtime.

seed
Random seed. Default is NULL, which generates the seed from R. Set to 0 to ignore the R seed.

dependent.variable.name
Name of outcome variable, needed if no formula given. For survival forests this is the time variable.

status.variable.name
Name of status variable, only applicable to survival data and needed if no formula given. Use 1 for event and 0 for censoring.

npairs
Number of variable pairs to sample for each split. Default is the square root of the number of independent variables divided by 2 (this number is rounded up).

classification
Only needed if data is a matrix. Set to TRUE to grow a classification forest.

Details
The effect importance measure (EIM) of interaction forests distinguishes quantitative and qualitative interaction effects (Peto, 1982). This is a common distinction as these two types of interaction effects are interpreted in different ways (see below). For both of these types, EIM values for each variable pair are obtained: the quantitative and qualitative EIM values.

Interaction forests target easily interpretable types of interaction effects. These can be communicated clearly using statements of the following kind: "The strength of the positive (negative) effect of variable A on the outcome depends on the level of variable B" for quantitative interactions, and "for observations with small values of variable B, the effect of variable A is positive (negative), but for observations with large values of B, the effect of A is negative (positive)" for qualitative interactions.

In addition to calculating EIM values for variable pairs, importance values for the individual variables are calculated as well, the univariable EIM values. These measure the variable importance as in the case of classical variable importance measures of random forests.

The effect importance mode can be set via the importance argument: "qualitative": Calculate only qualitative EIM values; "quantitative": Calculate only quantitative EIM values; "both"
interactionfor

(the default): Calculate qualitative and quantitative EIM values; "mainonly": Calculate only univariable EIM values.

The top variable pairs with largest quantitative and qualitative EIM values likely have quantitative and qualitative interactions, respectively, which have a considerable impact on prediction. The top variables with largest univariable EIM values likely have a considerable impact on prediction.

If the number of variables is larger than 100, not all possible variable pairs are considered, but, using a screening procedure, the 5000 variable pairs with the strongest indications of interaction effects are pre-selected.

NOTE: To make interpretations, it is crucial to investigate (visually) the forms the interaction effects of variable pairs with large quantitative and qualitative EIM values take. This can be done using the plot function `plot.interactionfor` (first overview) and `plotEffects`.

NOTE ALSO: As described in Hornung & Boulesteix (2022), in the case of data with larger numbers of variables (larger than 100, but more seriously for high-dimensional data), the univariable EIM values can be biased. Therefore, it is strongly recommended to interpret the univariable EIM values with caution, if the data are high-dimensional. If it is of interest to measure the univariable importance of the variables for high-dimensional data, an additional conventional random forest (e.g., using the `ranger` package) should be constructed and the variable importance measure values of this random forest be used for ranking the univariable effects.

For large data sets with many observations the calculation of the EIM values can become very costly - when using fully grown trees. Therefore, when calculating EIM values for data sets with more than 1000 observations we use the following maximum tree depths by default (argument: `simplify.large.n = TRUE`):

- if \( n \leq 1000 \): Use fully grown trees.
- if \( 1000 < n \leq 2000 \): Use tree depth 10.
- if \( 2000 < n \leq 5000 \): Use tree depth 7.
- if \( n > 5000 \): Use tree depth 5.

Extensive analyses in Hornung & Boulesteix (2022) suggest that by restricting the tree depth in this way, the EIM values that would result when using fully grown trees are approximated well. However, the prediction performance suffers, when using restricted trees. Therefore, we restrict the tree depth only when calculating the EIM values (if \( n > 1000 \)), but construct a second interaction forest with unrestricted tree depth, which is then used for prediction purposes.

Value

Object of class `interactionfor` with elements

- `predictions`: Predicted classes/values, based on out-of-bag samples (classification and regression only).
- `num.trees`: Number of trees.
- `num.independent.variables`: Number of independent variables.
- `unique.death.times`: Unique death times (survival only).
- `min.node.size`: Value of minimal node size used.
- `npairs`: Number of variable pairs sampled for each split.
interactionfor

eim.univ.sorted
Univariable EIM values sorted in decreasing order.
eim.univ
Univariable EIM values.
eim.qual.sorted
Qualitative EIM values sorted in decreasing order.
eim.qual
Qualitative EIM values.
eim.quant.sorted
Quantitative EIM values sorted in decreasing order.
The labeling of these values provides the information on the type of quantitative interactions the respective variable pairs feature. For example, consider a variable pair A and B and say the label reads "A large AND B small". This would mean that if the value of A is large and, at the same time, the value of B is small, the expected value of the outcome variable is (considerably) different from all other cases. For this type of quantitative interaction, the effect of B is weak for small values of A and strong for large values of B. See Hornung & Boulesteix (2022) for more information on the types of quantitative interaction effects targeted by interaction forest.
eim.quant
Quantitative EIM values. These values are labeled analoguously as those in eim.quant.sorted.
prediction.error
Overall out-of-bag prediction error. For classification this is the fraction of misclassified samples, for probability estimation the Brier score, for regression the mean squared error and for survival one minus Harrell’s C-index. This is 'NA' for data sets with more than 100 covariate variables, because for such data sets we pre-select the 5000 variable pairs with strongest indications of interaction effects. This pre-selection cannot be taken into account in the out-of-bag error estimation, which is why the out-of-bag error estimates would be (much) too optimistic for data sets with more than 100 covariate variables.
forest
Saved forest (If write.forest set to TRUE). Note that the variable IDs in the split.multvarIDs object do not necessarily represent the column number in R.
confusion.matrix
Contingency table for classes and predictions based on out-of-bag samples (classification only).
chf
Estimated cumulative hazard function for each sample (survival only).
survival
Estimated survival function for each sample (survival only).
splitrule
Splitting rule.
treetype
Type of forest/tree. classification, regression or survival.
r.squared
R squared. Also called explained variance or coefficient of determination (regression only). Computed on out-of-bag data.
call
Function call.
importance.mode
Importance mode used.
um.samples
Number of samples.
replace
Sample with replacement.
**interactionfor**

### eim.quant.rawlists

List containing the four vectors of un-adjusted 'raw' quantitative EIM values and the four vectors of adjusted EIM values. These are usually not required by the user. For each of the four types of quantitative splits there exists a separate vector of raw quantitative EIM values. For example, `eim.quant.large.small.raw` contains the raw quantitative EIM values of the quantitative split type associated with quantitative interaction effects for which the expected values of the outcome variable are different, if the value of variable A is large and, at the same time, the value of variable B is small. The list entries of the un-adjusted 'raw' quantitative EIM values are labeled with the suffix `.raw`, while the list entries of the adjusted quantitative EIM values miss this suffix. See Hornung & Boulesteix (2022) for details on the raw and adjusted EIM values.

### promispairs

List giving the indices of the variables in the pre-selected variable pairs. If the number of variables is at most 100, all variable pairs are considered.

### plotres

List of objects needed by the plot functions: `eim.univ.order` contains the sorting of the univariable EIM values in descending order, where the first element gives the index of the variable with largest EIM value, the second element the index of the variable with second-largest EIM value and so on; `eim.qual.order / eim.quant.order` contains the sorting in descending order of the qualitative / quantitative EIM values for the (pre-selected) variable pairs given by the object `promispairs` above. The first element gives the index of the (pre-selected) variable pair with largest qualitative / quantitative EIM value, the second element the index of the variable pair with second-largest qualitative / quantitative EIM value; `data` contains the data; `yvarname` is the name of the outcome variable (survival time for survival); `statusvarname` is the name of the status variable.

### Author(s)

Roman Hornung, Marvin N. Wright

### References


See Also

predict.divfor, plot.interactionfor, plotEffects

Examples

## Not run:

## Load package:

library("diversityForest")

## Set seed to make results reproducible:

set.seed(1234)

## Construct interaction forests and calculate EIM values:

# Binary outcome:

data(zoo)
modelcat <- interactionfor(dependent.variable.name = "type", data = zoo,
num.trees = 20)

# Metric outcome:

data(stock)
modelcont <- interactionfor(dependent.variable.name = "company10", data = stock,
num.trees = 20)

# Survival outcome:

library("survival")
mgus2$id <- NULL # 'mgus2' data set is contained in the 'survival' package

# categorical variables need to be of factor format - important!!
mgus2$sex <- factor(mgus2$sex)
mgus2$pstat <- factor(mgus2$pstat)

# Remove the second time variable 'ptime':
mgus2$ptime <- NULL

# Remove missing values:
mgus2 <- mgus2[complete.cases(mgus2),]

# Take subset to make the calculations less computationally
```r
# expensive for the example (in actual applications, we would of course
# use the whole data set):
mgus2sub <- mgus2[sample(1:nrow(mgus2), size=500),]

# Apply 'interactionfor':
modelsurv <- interactionfor(formula = Surv(futime, death) ~ ., data=mgus2sub, num.trees=20)

# NOTE: num.trees = 20 (in the above) would be much too small for practical
# purposes. This small number of trees was simply used to keep the
# runtime of the example short.
# The default number of trees is num.trees = 20000 if EIM values are calculated
# and num.trees = 2000 otherwise.

## Inspect the rankings of the variables and variable pairs with respect to
## the univariable, quantitative, and qualitative EIM values:

# Univariable EIM values:
modelcat$eim.univ.sorted

# Pairs with top quantitative EIM values:
modelcat$eim.quant.sorted[1:5]

# Pairs with top qualitative EIM values:
modelcat$eim.qual.sorted[1:5]

## Investigate visually the forms of the interaction effects of the variable pairs with
## largest quantitative and qualitative EIM values:

plot(modelcat)
plotEffects(modelcat, type="quant") # type="quant" is default.
plotEffects(modelcat, type="qual")

## Prediction:

# Separate 'zoo' data set randomly in training
# and test data:

data(zoo)
train.idx <- sample(nrow(zoo), 2/3 * nrow(zoo))
zoo.train <- zoo[train.idx,]
zoo.test <- zoo[-train.idx,]

# Construct interaction forest on training data:
# NOTE again: num.trees = 20 is specified too small for practical purposes.
modelcattrain <- interactionfor(dependent.variable.name = "type", data = zoo,
importance = "none", num.trees = 20)

# NOTE: Because we are only interested in prediction here, we do not
```
# calculate EIM values (by setting importance = "none"), because this
# speeds up calculations.

# Predict class values of the test data:
pred.zoo <- predict(modelcattrain, data = zoo.test)

# Compare predicted and true class values of the test data:
table(zoo.test$type, pred.zoo$predictions)

## End(Not run)

---

**plot.interactionfor**  
*Plot method for interactionfor objects*

**Description**

Plot function for interactionfor objects that allows to obtain a first overview of the result of the interaction forest analysis. This function visualises the distributions of the EIM values and the estimated forms of the bivariable influences of the variable pairs with largest quantitative and qualitative EIM values. Further visual exploration of the result of the interaction forest analysis should be conducted using `plotEffects`.

**Usage**

```r
## S3 method for class 'interactionfor'
plot(x, numpairsquant = 2, numpairsqual = 2, ...)
```

**Arguments**

- `x`: Object of class `interactionfor`.
- `numpairsquant`: The number of pairs with largest quantitative EIM values to plot. Default is 2.
- `numpairsqual`: The number of pairs with largest qualitative EIM values to plot. Default is 2.
- `...`: Further arguments passed to or from other methods.

**Details**

For details on the plots of the estimated forms of the bivariable influences of the variable pairs see `plotEffects`.

NOTE: The p-values shown in the plots are generally much too optimistic and MUST NOT be reported as the result of a statistical test for significance of interaction. To obtain adjusted p-values that would correspond to valid tests, it would be possible to multiply these p-values by the number of possible variable pairs, which would correspond to Bonferroni-adjusted p-values. See the 'Details' section of `plotEffects` for further explanation and guidance.

NOTE ALSO: As described in Hornung & Boulesteix (2022), in the case of data with larger numbers of variables (larger than 100, but more seriously for high-dimensional data), the univariable EIM values can be biased. Therefore, it is strongly recommended to interpret the univariable EIM
plot.interactionfor

Values with caution, if the data are high-dimensional. If it is of interest to measure the univariable importance of the variables for high-dimensional data, an additional conventional random forest (e.g., using the ranger package) should be constructed and the variable importance measure values of this random forest be used for ranking the univariable effects.

Value

A ggplot2 plot.

Author(s)

Roman Hornung

References


See Also

plotEffects

Examples

```r
## Not run:

## Load package:

library("diversityForest")

## Set seed to make results reproducible:

set.seed(1234)

## Construct interaction forest and calculate EIM values:

data(stock)

model <- interactionfor(dependent.variable.name = "company10", data = stock,
num.trees = 20)

# NOTE: num.trees = 20 (in the above) would be much too small for practical
# purposes. This small number of trees was simply used to keep the
# runtime of the example short.
```
# The default number of trees is num.trees = 20000 if EIM values are calculated
# and num.trees = 2000 otherwise.

## When using the plot() function without further specifications,
## by default the estimated bivariable influences of the two pairs with largest quantitative
## and qualitative EIM values are shown:
plot(model)

# It is, however, also possible to change the numbers of
# pairs with largest quantitative and qualitative EIM values
# to be shown:
plot(model, numpairsquant = 4, numpairsqual = 3)

## End(Not run)

---

**plotEffects**  
*Interaction forest plots: exploring interaction forest results through visualisation*

### Description

This function allows to visualise the (estimated) bivariable influences of pairs of variables (with large quantitative and qualitative EIM values) on the outcome. This step is crucial, because to interpret interaction effects between variable pairs with large quantitative and qualitative EIM values, it is necessary to learn about the forms these interaction effects take.

### Usage

```r
plotEffects(
  intobj,
  type = "quant",
  numpairs = 5,
  indpairs = NULL,
  pairs = NULL,
  allwith = NULL,
  pvalues = TRUE,
  twoplots = TRUE,
  addtitles = TRUE,
  plotit = TRUE
)
```
**plotEffects**

**Arguments**

- **intobj**: Object of class `interactionfor`.
- **type**: This can be either "quant" or "qual" and determines whether the plotted pairs are sorted according to either the quantitative or qualitative EIM values in decreasing order. Default is "quant".
- **numpairs**: The number of pairs to plot (default: 5). This is overwritten by `indpairs`.
- **indpairs**: Optional. The indices of the pairs in the sorted lists of quantitative (`type="quant"`) or qualitative EIM values to plot (`type="qual"`). This overwrites the `numpairs` argument.
- **pairs**: This can be used to specify the pairs to plot. It is an optional list of character string vectors, where each of these vectors has length two. Each list element corresponds to one pair, where the first character string gives the name of the first member of the respective pair to plot and the second character string gives the name of the second member. This argument overwrites `numpairs` and `indpairs`.
- **allwith**: This is an optional character string that can be set to the name of one of the variables. If provided, only variable pairs will be considered that feature the variable specified by this argument `allwith`. These pairs are again sorted in decreasing order according to the quantitative (`type="quant"`) or qualitative (`type="qual"`) EIM values and their number is restricted to the value given by `numpairs`. This argument `allwith` can be used, if it is of interest to learn whether a specific variable (e.g., sex or age) interacts with other variables in the data set and if so, which forms these interactions take.
- **pvalues**: Set to `TRUE` (default) to add to the plots p-values from tests for interaction effect obtained using classical parametric regression approaches. For categorical outcomes logistic regression is used, for metric outcomes linear regression and for survival outcomes Cox regression. NOTE: These p-values are generally much too optimistic and **MUST NOT** be reported as the result of a statistical test for significance of interaction. See the 'Details' section below for further details.
- **twoplots**: Set to `TRUE / FALSE` if for each plot page the results of two / one pair(s) of variables should be shown. Default is `TRUE`.
- **addtitles**: Set to `TRUE` (default) to add headings providing the names of the variables in each pair. If `type="quant"`, these headings also give information on the type of quantitative interaction effect. Setting `addtitles` to `FALSE` is, for example, useful, when the produced plots are intended for use in a publication, where these headings might not be desirable.
- **plotit**: This states whether the plots are actually plotted or merely returned as `ggplot` objects. Default is `TRUE`.

**Details**

For each considered pair the bivariable influence of both pair members on the outcome estimated using a two-dimensional flexible function is shown. Such visualisations make it possible to learn about the forms of the interaction effects between variable pairs with large EIM values. Moreover, these visualisations reveal (pathological) cases in which variable pairs do not show indications of
interaction effects despite featuring large EIM values.

For binary outcomes the estimated probabilities for the second class are predicted, for categorical outcomes with more than two classes the estimated probabilities for the largest class are predicted, for metric outcomes the means of the outcome are predicted, and for survival outcomes the log hazards ratio values compared to the median effect are predicted.

The kinds of estimates shown differ also according to whether both pair members are metric or only one of the two members is metric and the other one categorical or both pair members are categorical:

- If both pair members are metric and the outcome is categorical or metric we use two-dimensional LOESS regression, where in the case of categorical outcomes, to obtain probability estimates for the first class (or largest class for multi-class outcomes), we use the value ’1’ for the first class (largest class for multi-class outcomes) and the value ’0’ for the second class (all other classes for multi-class outcomes).

- If both pair members are metric and the outcome is survival we use a Cox proportional hazard additive model with a two-dimensional LOESS smooth (gamcox function from the 'MapGAM' package (version 1.2-5)) and in the rare cases for which the latter fails, we use classical Cox regression with an interaction term between the two covariates.

- If one pair member is metric and the other one categorical and the outcome is categorical or metric, we use LOESS regression between the outcome (coded as ’0’ and ’1’ in the case of categorical outcomes as described above) and the values of the metric variable separately for each category of the categorical variable. In the rare cases in which the LOESS regression fails we use classical linear regression.

- If one pair member is metric and the other one categorical and the outcome is survival, we use Cox regression with a linear tail-restricted cubic spline with four knots (univariable LOESS regression for survival outcomes does not seem to be available yet in R) separately for each category of the categorical variable. In cases in which the fitting of this spline regression fails we use classical Cox regression.

- If both pair members are categorical and the outcome is categorical or metric, we simply calculate the mean of the outcome (coded as ’0’ and ’1’ in the case of categorical outcomes as described above) for each possible combination of the categories of the two variables.

- If both pair members are categorical and the outcome is survival, we use classical Cox regression with an interaction term between the two variables (there is no need for any flexible modelling in this setting, because the Cox model with two categorical variables plus interaction term is saturated).

As described above (function argument: pvalues), there is an option to add p-values from tests for interaction effect to the plots. If at least one of the variables in the considered variable pair is categorical and features more than two categories, there are more than one interaction terms in the regression approaches used for testing, because the categorical variables are dummy-coded. Therefore, in these cases we obtain a p-value for each interaction term, to obtain a single p-value for the test for interaction we adjust these multiple p-values using the Holm-Bonferroni procedure and take the minimum of the adjusted p-values.

**NOTE:** These p-values are generally much too optimistic, in particular for small data sets and large numbers of variables. The reason for this overoptimism is that these p-values are not adjusted for the fact that we already used the data to find the variable pairs with strongest indications of interaction effects. This is similar to a multiple testing problem. Therefore, these p-values should only be seen as a rough guide to be interpreted very cautiously and **MUST NOT** be reported as the results of a
plotEffects

statistical test for significance of interaction. To obtain adjusted p-values that would correspond to valid tests, it would be possible to multiply these p-values by the number of possible pairs, which would correspond to Bonferroni-adjusted p-values. For example, assume that we have 30 covariate variables. In that case the number of possible pairs would be `\text{choose}(30, 2) = 435`, which is why we would need to multiply each p-value by 435 to obtain an adjusted p-value (or keep the original p-values and divide the significance level 0.05 by 435). Note, however, that Bonferroni-adjusted p-values deliver quite conservative results.

Value

A list of ggplot2 plots returned invisibly.

Author(s)

Roman Hornung

References


See Also

`plot.interactionfor`, `plotPair`

Examples

```r
## Not run:
## Load package:
library("diversityForest")

## Set seed to make results reproducible:
set.seed(1234)

data(stock)
model <- interactionfor(dependent.variable.name = "company10", data = stock,
num.trees = 20)
```

# NOTE: num.trees = 20 (in the above) would be much too small for practical purposes. This small number of trees was simply used to keep the runtime of the example short. The default number of trees is num.trees = 20000 if EIM values are calculated and num.trees = 2000 otherwise.

## Obtain a first overview by applying the plot() function for interaction for objects:

```
plot(model)
```

## Several possible application cases of the plotEffects() function:

- Visualise the estimated bivariable influences of the five variable pairs with the largest quantitative EIM values:
  ```r
  plotEffects(model) # type="quant" is default.
  ```

- Visualise the estimated bivariable influences of the five pairs with the largest qualitative EIM values:
  ```r
  plotEffects(model, type="qual")
  ```

- Visualise the estimated bivariable influences of all (eight) pairs that involve the variable "company7" sorted in decreasing order according to the qualitative EIM values:
  ```r
  plotEffects(model, allwith="company7", type="qual", numpairs=8)
  ```

- Visualise the estimated bivariable influences of the pairs with third and fifth largest qualitative EIM values:
  ```r
  plotEffects(model, type="qual", indpairs=c(3,5))
  ```

- Visualise the estimated bivariable influences of the pairs ("company3", "company5") and ("company1", "company9"):
  ```r
  plotEffects(model, pairs=list(c("company3", "company5"), c("company1", "company9")))
  ```

## Saving of plots generated with the plotEffects() function (e.g., for use in publications):

- Apply plotEffects() to obtain plots for the five variable pairs with the largest qualitative EIM values and store these plots in
# an object 'ps':

ps <- plotEffects(model, type="qual", pvalues=FALSE, twoplots=FALSE, addtitles=FALSE, plotit=FALSE)

# pvalues = FALSE states that no p-values should be shown in the plots,
# because these might not be desired in plots meant for publication.
# twoplots = FALSE ensures that we get one plot for each page instead of two plots per page.
# addtitles = FALSE removes the automatically generated titles, because these are likely
# not desired in publications.
# plotit = FALSE ensures that the plots are not displayed, but only returned (invisibly)
# by plotEffects().

# Save the plot with second largest qualitative EIM value:

p1 <- ps[[2]]

# Add title:
library("ggpubr")
p1 <- annotate_figure(p1, top = text_grob("My descriptive plot title 1", face = "bold", size = 14))
p1

# Save as PDF:
# library("ggplot2")
# ggsave(file="mypathfolder/FigureXY1.pdf", width=14, height=6)

# Save the plot with fifth largest qualitative EIM value:

p2 <- ps[[5]]

# Add title:
p2 <- annotate_figure(p2, top = text_grob("My descriptive plot title 2", face = "bold", size = 14))
p2

# Save as PDF:
# ggsave(file="mypathfolder/FigureXY1.pdf", width=14, height=6)

# Combine both of the above plots:
p <- ggarrange(p1, p2, nrow = 2)
p

# Save the combined plot:
# ggsave(file="mypathfolder/FigureXYcombined.pdf", width=14, height=11)

# NOTE: Using plotEffects() it is not possible to change the plots
# themselves (by e.g., increasing the label sizes or changing the
# axes ranges). However, the function plotPair() can be used to change
# the plots themselves.

## End(Not run)
plotPair

Plot of the (estimated) simultaneous influence of two variables

Description

This function allows to visualise the (estimated) bivariable influence of a single specific pair of variables on the outcome. The estimation and plotting is performed in the same way as in plotEffects. However, plotPair does not require an interaction for object and can thus be used also without a constructed interaction forest.

Usage

plotPair(
  pair,
  yvarname,
  statusvarname = NULL,
  data,
  levelsorder1 = NULL,
  levelsorder2 = NULL,
  pvalue = TRUE,
  returnseparate = FALSE,
  intobj = NULL
)

Arguments

pair
Character string vector of length two, where the first character string gives the name of the first member of the respective pair to plot and the second character string gives the name of the second member.

yvarname
Name of outcome variable.

statusvarname
Name of status variable, only applicable to survival data.

data
Data frame containing the variables.

levelsorder1
Optional. Order the categories of the first variable should have in the plot (if it is categorical). Character string vector, where the i-th entry contains the name of the category that should take the i-th place in the ordering of the categories of the first variable.

levelsorder2
Optional. Order the categories of the second variable should have in the plot (if it is categorical). Character string vector specified in an analogous way as levelsorder1.

pvalue
Set to TRUE (default) to add to the plot a p-value from a test for interaction effect obtained using a classical parametric regression approach. For categorical outcomes logistic regression is used, for metric outcomes linear regression and for survival outcomes Cox regression. See the ‘Details’ section of plotEffects for further details.
returnseparate Set to TRUE to return invisibly the two generated ggplot plots separately in the form of a list. The latter option is useful, because it allows to manipulate the resulting plots (label size etc.) and makes it possible to consider only one of the two plots. The default is FALSE, which results in the two plots being returned together in the form of a ggarrange object.

intobj Optional. Object of class interactionfor. If this is provided, the ordering of the categories obtained when constructing the interaction forest will be used for categorical variables. See Hornung & Boulesteix (2021) for details.

Details
See the 'Details' section of plotEffects.

Value
A ggplot2 plot.

Author(s)
Roman Hornung

References

See Also
plotEffects, plot.interactionfor

Examples
## Not run:
## Load package:
library("diversityForest")

## Visualise the estimated bivariable influence of 'toothed' and 'feathers' on
## the probability of type="mammal":
data(zoo)
plotPair(pair = c("toothed", "feathers"), yvarname="type", data = zoo)
### Visualise the estimated bivariable influence of 'creat' and 'hgb' on survival (more precisely, on the log hazards ratio compared to the median effect):

library("survival")
mgus2compl <- mgus2[complete.cases(mgus2),]
plotPair(pair=c("creat", "hgb"), yvarname="futime", statusvarname = "death", data=mgus2compl)

# Problem: The outliers in the left plot make it difficult to see what is going on in the region with creat values smaller than about two even though the majority of values lie there.

# -- Solution: We re-run the above line setting returnseparate = TRUE, because this allows to get the two ggplot plots separately, which can then be manipulated to change the x-axis range in order to remove the outliers:

ps <- plotPair(pair=c("creat", "hgb"), yvarname="futime", statusvarname = "death", data=mgus2compl, returnseparate = TRUE)

# Change the x-axis range:
library("ggplot2")
ps[[1]] + xlim(c(0.5,2))
# Save the plot:
# ggsave(file="mypath/folder/FigureXY1.pdf", width=7, height=6)

# We can, for example, also change the label sizes of the second plot:
# With original label sizes:
ps[[2]]
# With larger label sizes:
ps[[2]] + theme(axis.title=element_text(size=15))
# Save the plot:
# library("ggplot2")
# ggsave(file="mypath/folder/FigureXY2.pdf", width=7, height=6)

## End(Not run)

---

**predict.divfor**

**Diversity Forest prediction**

### Description
Prediction with new data and a saved forest from `divfor`.

### Usage
```
## S3 method for class 'divfor'
```
predict.difor

predict(
  object,
  data = NULL,
  predict.all = FALSE,
  num.trees = object$num.trees,
  type = "response",
  se.method = "infjack",
  quantiles = c(0.1, 0.5, 0.9),
  seed = NULL,
  num.threads = NULL,
  verbose = TRUE,
  ...
)

Arguments

object  divfor object.
data     New test data of class data.frame or gwaa.data (GenABEL).
predict.all Return individual predictions for each tree instead of aggregated predictions for all trees. Return a matrix (sample x tree) for classification and regression, a 3d array for probability estimation (sample x class x tree) and survival (sample x time x tree).
num.trees Number of trees used for prediction. The first num.trees in the forest are used.
type     Type of prediction. One of 'response', 'se', 'terminalNodes', 'quantiles' with default 'response'. See below for details.
se.method Method to compute standard errors. One of 'jack', 'infjack' with default 'infjack'. Only applicable if type = 'se'. See below for details.
quantiles Vector of quantiles for quantile prediction. Set type = 'quantiles' to use.
seed     Random seed. Default is NULL, which generates the seed from R. Set to 0 to ignore the R seed. The seed is used in case of ties in classification mode.
num.threads Number of threads. Default is number of CPUs available.
verbose  Verbose output on or off.
...       further arguments passed to or from other methods.

Details

This package is a fork of the R package 'ranger' that implements random forests using an efficient C++ implementation. More precisely, 'diversityForest' was written by modifying the code of 'ranger', version 0.11.0. Therefore, details on further functionalities of the code that are not presented in the help pages of 'diversityForest' are found in the help pages of 'ranger' (version 0.11.0). The code in the example sections of divfor and tunedivfor can be used as a template for all common application scenarios with respect to classification, regression and survival prediction using univariable, binary splitting. Some function arguments adopted from the 'ranger' package may not be useable with diversity forests (for the current package version).
Value

Object of class `divfor.prediction` with elements
predictions
unique.death.times
chf
survival
num.trees
num.independent.variables
treetype
num.samples

Predicted classes/values (only for classification and regression)
Unique death times (only for survival).
Estimated cumulative hazard function for each sample (only for survival).
Estimated survival function for each sample (only for survival).
Number of trees.
Number of independent variables.
Type of forest/tree. Classification, regression or survival.
Number of samples.

Author(s)

Marvin N. Wright

References

• Hornung, R. (2022). Diversity forests: Using split sampling to enable innovative complex
  split procedures in random forests. SN Computer Science 3(2):1, <doi: 10.1007/s42979021-
  009201>.
  Dimensional Data in C++ and R. Journal of Statistical Software 77:1-17, <doi: 10.18637/
  jss.v077.i01>.
  Jackknife and the Infinitesimal Jackknife. Journal of Machine Learning Research 15:1625-
  1651.
  7:983-999.

See Also
divfor

predict.interactionfor

Interaction Forest prediction

Description

Prediction with new data and a saved interaction forest from interactionfor.

Usage

```r
## S3 method for class 'interactionfor'
predict(
  object,
  data = NULL,
  predict.all = FALSE,
)```
predict.interactionfor

num.trees = object$num.trees,
type = "response",
se.method = "infjack",
quantiles = c(0.1, 0.5, 0.9),
seed = NULL,
num.threads = NULL,
verbose = TRUE,
...
)

Arguments

object interactionfor object.
data New test data of class data.frame or gwaa.data (GenABEL).
predict.all Return individual predictions for each tree instead of aggregated predictions for all trees. Return a matrix (sample x tree) for classification and regression, a 3d array for probability estimation (sample x class x tree) and survival (sample x time x tree).
num.trees Number of trees used for prediction. The first num.trees in the forest are used.
type Type of prediction. One of 'response', 'se', 'terminalNodes', 'quantiles' with default 'response'. See below for details.
se.method Method to compute standard errors. One of 'jack', 'infjack' with default 'infjack'. Only applicable if type = 'se'. See below for details.
quantiles Vector of quantiles for quantile prediction. Set type = 'quantiles' to use.
seed Random seed. Default is NULL, which generates the seed from R. Set to 0 to ignore the R seed. The seed is used in case of ties in classification mode.
num.threads Number of threads. Default is number of CPUs available.
verbose Verbose output on or off.
... further arguments passed to or from other methods.

Details

Note that his package is a fork of the R package 'ranger' that implements random forests using an efficient C++ implementation. The documentation is in large parts taken from 'ranger', where some parts of the documentation may not apply to (the current version of) the 'diversityForest' package. Details on further functionalities of the code that are not presented in the help pages of 'diversityForest' are found in the help pages of 'ranger' (version 0.11.0).

Value

Object of class interaction.prediction with elements

predictions Predicted classes/values (only for classification and regression)
unique.death.times Unique death times (only for survival).
chf Estimated cumulative hazard function for each sample (only for survival).
survival Estimated survival function for each sample (only for survival).
stock

num.trees Number of trees.
num.independent.variables Number of independent variables.
treetype Type of forest/tree. Classification, regression or survival.
num.samples Number of samples.

Author(s)

Marvin N. Wright, Roman Hornung

References


See Also

interactionfor

stock Data on stock prices of aerospace companies

Description

This data set contains 950 daily stock prices from January 1988 through October 1991, for ten aerospace companies. The names of the companies are anonymised and the stock prices for one of these companies (company10) were flagged as the outcome variable. Thus, for this data set, both the outcome and the covariates were metric.

Format

A data frame with 950 observations, nine covariates and one metric outcome variable

Details

The variables are as follows: covariates: company1, ..., company9, outcome variable: company10.
**Source**

OpenML: data.name: stock, data.id: 223, link: [https://www.openml.org/d/223/](https://www.openml.org/d/223/)

**References**


**Examples**

```r
## Load data:
data(stock)

## Dimension of data:
dim(stock)

## First rows of data:
head(stock)
```

**tunefdivfor**

*Optimization of the values of the tuning parameters nsplits and proptry*

**Description**

First, both for `nsplits` and `proptry` a grid of possible values may be provided, where default grids are used if no grids are provided. Second, for each pairwise combination of values from these two grids a forest is constructed. Third, that pair of `nsplits` and `proptry` values is used as the optimized set of parameter values that is associated with the smallest out-of-bag prediction error. If several pairs of parameter values are associated with the same smallest out-of-bag prediction error, the pair with the smallest (parameter) values is used.

**Usage**

```r
tunefdivfor(
    formula = NULL,
data = NULL,
    nsplitsgrid = c(2, 5, 10, 30, 50, 100, 200),
    proptrygrid = c(0.05, 1),
    num.trees.pre = 500
)
```
Arguments

- **formula**: Object of class formula or character describing the model to fit. Interaction terms supported only for numerical variables.
- **data**: Training data of class data.frame, matrix, dgCMatrix (Matrix) or gwaa.data (GenABEL).
- **nsplitsgrid**: Grid of values to consider for nsplits. Default grid: 2, 5, 10, 30, 50, 100, 200.
- **proptrygrid**: Grid of values to consider for proptry. Default grid: 0.05, 1.
- **num.trees.pre**: Number of trees used for each forest constructed during tuning parameter optimization. Default is 500.

Value

List with elements

- **nsplitsopt**: Optimized value of nsplits.
- **proptryopt**: Optimized value of proptry.
- **tunegrid**: Two-dimensional data.frame, where each row contains one pair of values considered for nsplits (first entry) and proptry (second entry).
- **ooberrs**: The out-of-bag prediction errors obtained for each pair of values considered for nsplits and proptry, where the ordering of pairs of values is the same as in tunegrid (see above).

Author(s)

Roman Hornung

References


See Also

divfor

Examples

```r
# Load package:

library("diversityForest")```
## Set seed to obtain reproducible results:

```r
set.seed(1234)
```

## Tuning parameter optimization for the iris data set:

```r
tuneres <- tunedivfor(formula = Species ~ ., data = iris, num.trees.pre = 20)
```

# NOTE: `num.trees.pre = 20` is specified too small for practical purposes - the out-of-bag error estimates of the forests constructed during optimization will be much too variable!!

# In practice, `num.trees.pre = 500` (default value) or a larger number should be used.

```r
tuneres
```

- `tuneres$nsplitsopt`
- `tuneres$proptryopt`
- `tuneres$tunegrid`
- `tuneres$ooberrs`

---

**zoo**

*Data on biological species*

### Description

This data set describes 101 different biological species using 16 simple attributes, where 15 of these are binary and one is metric (the number of legs). The outcome "mammal vs. other" (type) is binary.

### Format

A data frame with 101 observations, 16 covariates and one binary outcome variable

### Details

The variables are as follows:

- `hair`. factor. Presence of hairs (true = yes; false = no)
- `feathers`. factor. Presence of feathers (true = yes; false = no)
- `eggs`. factor. Does the species lay eggs? (true = yes; false = no)
- `milk`. factor. Does the species give milk? (true = yes; false = no)
- `airborne`. factor. Does the species fly? (true = yes; false = no)
- `aquatic`. factor. Does the species live in the water? (true = yes; false = no)
- `predator`. factor. Is the species a predator? (true = yes; false = no)
- `toothed`. factor. Presence of teeth (true = yes; false = no)
• backbone. factor. Presence of backbone (true = yes; false = no)
• breathes. factor. Does the species breathe with lungs? (true = yes; false = no)
• venomous. factor. Is the species venomous? (true = yes; false = no)
• fins. factor. Presence of fins (true = yes; false = no)
• legs. metric. Number of legs
• tail. factor. Presence of tail (true = yes; false = no)
• domestic. factor. Is the species domestic? (true = yes; false = no)
• catsize. factor. Is the species large? (true = yes; false = no)
• type. factor. Binary outcome variable - type of species ('mammal' vs. 'other')

The original openML dataset contains an additional variable animal, which is removed in this version of the data set. This variable provided the names of all species.

Source

OpenML: data.name: zoo, data.id: 965, link: https://www.openml.org/d/965/

References


Examples

```r
## ' Load data:
data(zoo)

## ' Numbers of observations in the two classes:
table(zoo$type)

## ' Dimension of data:
dim(zoo)

## ' First rows of data:
head(zoo)
```
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