Package ‘semtree’

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Type Package

Title Recursive Partitioning for Structural Equation Models

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Depends R (>= 2.10), OpenMx (>= 2.6.9),

Imports rpart, rpart.plot (>= 3.0.6), lavaan, cluster, ggplot2, tidyr, dplyr, methods, strucchange, sandwich, zoo, crayon, clisymbols, future.apply, data.table, expm, gridBase

Suggests knitr, rmarkdown, viridis, MASS, psych, psychTools, testthat, future, ctsemOMX

Description SEM Trees and SEM Forests -- an extension of model-based decision trees and forests to Structural Equation Models (SEM). SEM trees hierarchically split empirical data into homogeneous groups each sharing similar data patterns with respect to a SEM by recursively selecting optimal predictors of these differences. SEM forests are an extension of SEM trees. They are ensembles of SEM trees each built on a random sample of the original data. By aggregating over a forest, we obtain measures of variable importance that are more robust than measures from single trees. A description of the method was published by Brandmaier, von Oertzen, McArdle, & Lindenberger (2013) <doi:10.1037/a0030001> and Arnold, Voelkle, & Brandmaier (2020) <doi:10.3389/fpsyg.2020.564403>.

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NeedsCompilation no

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Contents

`semtree-package` *SEM Tree Package*

Description

SEM Tree Package

Usage

```
.SCALE_METRIC
```

Format

An object of class `numeric` of length 1.

`biodiversity` *Quantify bio diversity of a SEM Forest*

Description

A function to calculate biodiversity of a `semforest` object.

Usage

```
biodiversity(x, aggregate.fun = median)
```

Arguments

`x`	A `semforest` object
`aggregate.fun`	Takes a function to apply to the vector of pairwise diversities. By default, this is the median.

Author(s)

Andreas M. Brandmaier

`boruta` *Run the Boruta algorithm on a sem tree*

Description

Grows a series of SEM Forests following the boruta algorithm to determine feature importance as moderators of the underlying model.

Usage

```
boruta(
  model,
  data,
  control = NULL,
  predictors = NULL,
  maxRuns = 30,
  pAdjMethod = "none",
  alpha = 0.05,
  verbose = FALSE,
  quant = 1,
  ...
)
```

Arguments

`model`	A template SEM. Same as in `semtree`.
`data`	A dataframe to boruta on. Same as in `semtree`.
`control`	A semforest control object to set forest parameters.
`predictors`	An optional list of covariates. See semtree code example.
`maxRuns`	Maximum number of boruta search cycles
`pAdjMethod`	A value from p.adjust.methods defining a multiple testing correction method
`alpha`	p-value cutoff for decision making. Default .05
`verbose`	Verbosity level for boruta processing similar to the same argument in semtree.control and semforest.control
`quant`	Quantile for selection. Default 1.
`...`	Optional parameters to undefined subfunctions

Value

A vim object with several elements that need work. Of particular note, ‘$importance‘ carries mean importance; ‘$decision‘ denotes Accepted/Rejected/Tentative; ‘$impHistory‘ has the entire varimp history; and ‘$details‘ has exit values for each parameter.

Author(s)

Priyanka Paul, Timothy R. Brick, Andreas Brandmaier

See Also

`semtree` `semforest`

`coef.semtree` *Return the parameter estimates of a given leaf of a SEM tree*

Description

Return the parameter estimates of a given leaf of a SEM tree

Usage

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

Arguments

`object`	semtree. A SEM tree node.
`...`	Extra arguments. Currently unused. @exportS3Method coef semtree

---

`computePval_maxLR` *Wrapper function for computing the maxLR corrected p value from strucchange*

Description

Wrapper function for computing the maxLR corrected p value from strucchange

Usage

```
computePval_maxLR(maxLR, q, covariate, from, to, nrep)
```

Arguments

`maxLR`	maximum of the LR test statistics
`q`	number of free SEM parameters / degrees of freedom
`covariate`	covariate under evaluation. This is important to get the level of measurement from the covariate and the bin size for ordinal and categorical covariates.
`from`	numeric from interval (0, 1) specifying start of trimmed sample period. With the default from = 0.15 the first and last 15 percent of observations are trimmed. This is only needed for continuous covariates.
`to`	numeric from interval (0, 1) specifying end of trimmed sample period. By default, to is 1.
`nrep`	numeric. Number of replications used for simulating from the asymptotic distribution (passed to efpFunctional). Only needed for ordinal covariates.

Value

Numeric. p value for maximally selected LR statistic

Author(s)

Manuel Arnold

`diversityMatrix` *Diversity Matrix*

Description

Computes a diversity matrix using a distance function between trees

Usage

```
diversityMatrix(forest, divergence = klsym, showProgressBar = TRUE)
```

Arguments

`forest`	A SEM forest
`divergence`	A divergence function such as hellinger or klsym
`showProgressBar`	Boolean. Show a progress bar.

`evaluate` *Average Deviance of a Dataset given a Forest*

Description

Evaluates the average deviance (-2LL) of a dataset given a forest.

Usage

```
evaluate(x, data = NULL, ...)
```

Arguments

`x`	A fitted `semforest` object
`data`	A data.frame
`...`	No extra parameters yet.

Value

Average deviance

Author(s)

Andreas M. Brandmaier

References

Brandmaier, A.M., Oertzen, T. v., McArdle, J.J., & Lindenberger, U. (2013). Structural equation model trees. *Psychological Methods*, 18(1), 71-86.

See Also

`evaluateDataLikelihood`, `semtree`, `semforest`

`evaluateDataLikelihood` *Compute the Negative Two-Loglikelihood of some data given a model (either OpenMx or lavaan)*

Description

This helper function is used in the `semforest` `varimp` and `proximity` aggregate functions.

Usage

```
evaluateDataLikelihood(
  model,
  data,
  data_type = "raw",
  loglik = c("default", "model", "mvn")
)
```

Arguments

`model`	A model as used in `semtree` and `semforest`.
`data`	Data set to apply to a fitted model.
`data_type`	Type of data ("raw", "cov", "cor")
`loglik`	Character. Either 'model' for model-based evaluation or 'mvn' for multivariate normal density.

Value

Returns a -2LL model fit for the model

Author(s)

Andreas M. Brandmaier, John J. Prindle

References

Brandmaier, A.M., Oertzen, T. v., McArdle, J.J., & Lindenberger, U. (2013). Structural equation model trees. *Psychological Methods*, 18(1), 71-86.

See Also

`semtree`, `semforest`

`evaluateTree` *Evaluate Tree -2LL*

Description

A helper function to evaluate the negative two log-likelihood (-2LL) of leaf (terminal) nodes for a dataset. When given a `semtree` and a unique dataset, the model estimates -2LL for the tree parameters and data subsets that fit the tree branching criteria.

Usage

```
evaluateTree(
  tree,
  test_set,
  data_type = "raw",
  leaf_ids = NULL,
  loglik = c("default", "model", "mvn")
)
```

Arguments

`tree`	A fitted `semtree` object
`test_set`	Dataset to fit to a fitted `semtree` object
`data_type`	type of data ("raw", "cov", "cor")
`leaf_ids`	Identifies which nodes are leaf nodes. Default is NULL, which checks model for leaf nodes and fills this information in automatically.
`loglik`	Algorithm to compute log likelihood. The default is 'model' and refers to a model-based computation. This is preferable because it is more general. As an alternative, 'mvn' computes the log likelihood based on the multivariate normal density and the model-implied mean and covariance matrix.

Value

A list with two elements:

`deviance`	Combined -2LL for leaf node models of the tree.
`num_models`	Number of leaf nodes used for the deviance calculations.

Author(s)

Andreas M. Brandmaier, John J. Prindle

References

Brandmaier, A.M., Oertzen, T. v., McArdle, J.J., & Lindenberger, U. (2013). Structural equation model trees. *Psychological Methods*, 18(1), 71-86.

See Also

`evaluateDataLikelihood`, `semtree`, `semforest`

`findOtherSplits` *Find Other Node Split Values*

Description

Search tool to search nodes for alternative splitting values found during the `semtree` process. Given a particular node, competing split values are listed assuming they also meet the criteria for a significant splitting value as set by `semtree.control`.

Usage

```
findOtherSplits(node, tree)
```

Arguments

`node`	A node from a `semtree` object.
`tree`	A `semtree` object which the node is part of.

Value

A `data.frame()` with rows corresponding to the variable names and split values for alternative splits found in the node of interest. ...

Author(s)

Andreas M. Brandmaier, John J. Prindle

References

Brandmaier, A.M., Oertzen, T. v., McArdle, J.J., & Lindenberger, U. (2013). Structural equation model trees. *Psychological Methods*, 18(1), 71-86.

`fitSubmodels` *Fit multigroup model for evaluating a candidate split*

Description

Fit multigroup model for evaluating a candidate split

Usage

```
fitSubmodels(
  model,
  subset1,
  subset2,
  control,
  invariance = NULL,
  return.models = FALSE
)
```

Arguments

`model`	A model specification that is used as template for each of the two groups
`subset1`	Dataset for the first group model
`subset2`	Dataset for the second group model
`control`	a `semtree.control` object
`invariance`	fit models with invariant parameters if given. NULL otherwise (default).
`return.models`	boolean. Return the fitted models returns NA if fit fails

---

`getDepth` *Get the depth (or, height) a tree.*

Description

Returns the length of the longest path from a root node to a leaf node.

Usage

```
getDepth(tree)
```

Arguments

`tree`	A `semtree` object

Author(s)

Andreas M. Brandmaier

References

Brandmaier, A.M., Oertzen, T. v., McArdle, J.J., & Lindenberger, U. (2013). Structural equation model trees. *Psychological Methods*, 18(1), 71-86.

`getHeight` *Determine Height of a Tree*

Description

Returns height of a SEM Tree, which equals to the length of the longest path from root to a terminal node.

Usage

```
getHeight(tree)
```

Arguments

`tree`	A SEM tree.

Author(s)

Andreas M. Brandmaier, John J. Prindle

References

Brandmaier, A.M., Oertzen, T. v., McArdle, J.J., & Lindenberger, U. (2013). Structural equation model trees. *Psychological Methods*, 18(1), 71-86.

`getLeafs` *Get a list of all leafs in a tree*

Description

Get a list of all leafs in a tree by recursively searching the tree starting at the given node (if not `data` object is given. If `data` is given, the function returns the leafs that are predicted for each row of the given data.

Usage

```
getLeafs(tree, data = NULL)
```

Arguments

`tree`	A `semtree` object
`data`	A `data.frame`

Author(s)

Andreas M. Brandmaier

References

Brandmaier, A.M., Oertzen, T. v., McArdle, J.J., & Lindenberger, U. (2013). Structural equation model trees. *Psychological Methods*, 18(1), 71-86.

`getNodeById` *Get Node By Id*

Description

Return a node matching a given node ID

Usage

```
getNodeById(tree, id)
```

Arguments

`tree`	A SEM Tree object.
`id`	Numeric. A Node id.

Author(s)

Andreas M. Brandmaier, John J. Prindle

References

Brandmaier, A.M., Oertzen, T. v., McArdle, J.J., & Lindenberger, U. (2013). Structural equation model trees. *Psychological Methods*, 18(1), 71-86.

`getNumNodes` *Tree Size*

Description

Counts the number of nodes in a tree.

Usage

```
getNumNodes(tree)
```

Arguments

`tree`	A SEM tree object.

Author(s)

Andreas M. Brandmaier, John J. Prindle

References

Brandmaier, A.M., Oertzen, T. v., McArdle, J.J., & Lindenberger, U. (2013). Structural equation model trees. *Psychological Methods*, 18(1), 71-86.

`getParDiffForest` *Return list with parameter differences of a forest*

Description

Returns a list of tables with some measure of parameter differences between post-split nodes.

Usage

```
getParDiffForest(forest, measure = "wald", normalize = FALSE)
```

Arguments

`forest`	a semforest object.
`measure`	a character. "wald" (default) gives the squared parameter differences divided by their pooled standard errors. test" gives the contributions of the parameters to the test statistic. "raw" gives the absolute values of the parameter differences.
`normalize`	logical value; if TRUE parameter differences of each split are divided by sum of all differences the corresponding split. Set to FALSE by default.

Value

A list with data.frames containing parameter differences for each tree of the forest. The rows of the data.frames correspond to the non-leaf nodes of the respective trees. The first column contains the name of the predictor variables and the remaining columns contain the parameter differences. The rows of the data.frames are named by the node IDs as given `getNodeById` and the columns are named as in `coef`.

Author(s)

Manuel Arnold

`getParDiffTree` *Return table with parameter differences of a tree*

Description

Returns a table with some measure of parameter differences between post-split nodes.

Usage

```
getParDiffTree(tree, measure = "wald", normalize = FALSE)
```

Arguments

`tree`	a semtree object.
`measure`	a character. "wald" (default) gives the squared parameter differences divided by their pooled standard errors. "test" gives the contributions of the parameters to the test statistic."raw" gives the absolute values of the parameter differences.
`normalize`	logical value; if TRUE parameter differences of each split are divided by sum of all differences the corresponding split. Set to FALSE by default.

Value

A matrix containing parameter differences. The matrix has n rows and k columns, where n is the number of non-leaf nodes of the tree and k is the number of model parameters. The rows are named by the node IDs as given `getNodeById` and the columns are named as in `coef`.

Author(s)

Manuel Arnold

`getTerminalNodes` *Returns all leafs of a tree*

Description

Returns all leafs (=terminal nodes) of a tree.

Usage

```
getTerminalNodes(tree)
```

Arguments

`tree`	A semtree object.

Author(s)

Andreas M. Brandmaier, John J. Prindle

References

Brandmaier, A.M., Oertzen, T. v., McArdle, J.J., & Lindenberger, U. (2013). Structural equation model trees. *Psychological Methods*, 18(1), 71-86.

`isLeaf` *Test whether a semtree object is a leaf.*

Description

Tests whether a semtree object is a leaf. Returns TRUE or FALSE.

Usage

```
isLeaf(tree)
```

Arguments

`tree`	A `semtree` object

Author(s)

Andreas M. Brandmaier

References

Brandmaier, A.M., Oertzen, T. v., McArdle, J.J., & Lindenberger, U. (2013). Structural equation model trees. *Psychological Methods*, 18(1), 71-86.

`kl` *Distances*

Description

Divergence measures for multivariate normal distributions as used in the diversityMatrix function.

Usage

```
kl(mu1, cov1, mu2, cov2)
```

Arguments

`mu1`	Mean vector
`cov1`	Covariance matrix
`mu2`	Mean vector
`cov2`	Covariance matrix

`lgcm` *Simulated Linear Latent Growth Curve Data*

Description

This data set provides simple data to fit with a LGCM.

Format

`lgcm` is a matrix containing 400 rows and 8 columns of simulated data. Longitudinal observations are o1-o5. Covariates are agegroup, training, and noise.

Author(s)

Andreas M. Brandmaier <`brandmaier@mpib-berlin.mpg.de`>

`merge.semforest` *Merge two SEM forests*

Description

This overrides generic base::merge() to merge two forests into one.

Usage

```
## S3 method for class 'semforest'
merge(x, y, ...)
```

Arguments

`x`	A SEM Forest
`y`	A second SEM Forest
`...`	Extra arguments. Currently unused.

Author(s)

Andreas M. Brandmaier, John J. Prindle

References

Brandmaier, A.M., Oertzen, T. v., McArdle, J.J., & Lindenberger, U. (2013). Structural equation model trees. *Psychological Methods*, 18(1), 71-86.

See Also

`semtree`

`modelEstimates` *Returns all estimates of a tree*

Description

Return model estimates of the tree.

Usage

```
modelEstimates(tree, ...)
```

Arguments

`tree`	A semtree object.
`...`	Optional arguments.

Author(s)

Andreas M. Brandmaier, John J. Prindle

References

Brandmaier, A.M., Oertzen, T. v., McArdle, J.J., & Lindenberger, U. (2013). Structural equation model trees. *Psychological Methods*, 18(1), 71-86.

`outliers` *Find outliers based on case proximity*

Description

Compute outlier score based on proximity matrix.

Usage

```
outliers(prox)
```

Arguments

`prox`	A proximity matrix.

Author(s)

Andreas M. Brandmaier, John J. Prindle

References

Brandmaier, A.M., Oertzen, T. v., McArdle, J.J., & Lindenberger, U. (2013). Structural equation model trees. *Psychological Methods*, 18(1), 71-86.

See Also

`proximity`

`parameters` *SEMtrees Parameter Estimates Table*

Description

Returns a table of parameters with columns corresponding to freely estimated parameters and rows corresponding to nodes in the tree.

Usage

```
parameters(tree, leafs.only = TRUE)
```

Arguments

`tree`	A SEMtree object obtained from `semtree`
`leafs.only`	Default = TRUE. Only the terminal nodes (leafs) are printed. If set to FALSE, all node parameters are written to the `data.frame`.

Details

The row names of the resulting data frame correspond to internal node ids and the column names correspond to parameters in the SEM. Standard errors of the estimates can be obtained from `parameters`.

Value

Returns a `data.frame` with rows for parameters and columns for terminal nodes.

Author(s)

Andreas M. Brandmaier, John J. Prindle

References

Brandmaier, A.M., Oertzen, T. v., McArdle, J.J., & Lindenberger, U. (2013). Structural equation model trees. *Psychological Methods*, 18(1), 71-86.

See Also

`semtree`, `semtree.control`, `se`

`partialDependence` *Compute partial dependence*

Description

Compute the partial dependence of a predictor, or set of predictors, on a model parameter.

Usage

```
partialDependence(
  x,
  data,
  reference.var,
  support = 20,
  points = NULL,
  mc = NULL,
  FUN = "median",
  ...
)
```

Arguments

`x`	An object for which a method exists
`data`	Optional `data.frame` that was used to train the model.
`reference.var`	Character vector, referring to the (independent) reference variable or variables for which partial dependence is calculated. Providing two (or more) variables allows for probing interactions, but note that this is computationally expensive.
`support`	Integer. Number of grid points for interpolating the `reference.var`. Alternatively, use `points` for one or more variables named in `reference.var`.
`points`	Named list, with elements corresponding to `reference.var` . Use this argument to provide specific points for which to obtain marginal dependence values; for example, the mean and +/- 1SD of `reference.var`.
`mc`	Integer. If `mc` is not `NULL`, the function will sample `mc` number of rows from `data` with replacement, to estimate marginal dependency using Monte Carlo integration. This is less computationally expensive.
`FUN`	Character string with function used to integrate predictions across all elements of `x`.
`...`	Extra arguments passed to `FUN`.

Author(s)

Caspar J. Van Lissa, , Andreas M. Brandmaier

`partialDependence_data` *Create dataset to compute partial dependence*

Description

Create a dataset with fixed values for `reference.var` for all other values of `data`, or using `mc` random samples from `data` (Monte Carlo integration).

Usage

```
partialDependence_data(
  data,
  reference.var,
  support = 20,
  points = NULL,
  mc = NULL,
  keep_id = FALSE
)
```

Arguments

`data`	The `data.frame` that was used to train the model.
`reference.var`	Character vector, referring to the (independent) reference variable or variables for which partial dependence is calculated. Providing two (or more) variables allows for probing interactions, but note that this is computationally expensive.
`support`	Integer. Number of grid points for interpolating the `reference.var`. Alternatively, use `points` for one or more variables named in `reference.var`.
`points`	Named list, with elements corresponding to `reference.var` . Use this argument to provide specific points for which to obtain marginal dependence values; for example, the mean and +/- 1SD of `reference.var`.
`mc`	Integer. If `mc` is not `NULL`, the function will sample `mc` number of rows from `data` with replacement, to estimate
`keep_id`	Boolean. Default is false. Should output contain a row id column? marginal dependency using Monte Carlo integration. This is less computationally expensive.

Author(s)

Caspar J. Van Lissa

`partialDependence_growth`

Compute partial dependence for latent growth models

Description

Compute the partial dependence of a predictor, or set of predictors, on the predicted trajectory of a latent growth model.

Usage

```
partialDependence_growth(
  x,
  data,
  reference.var,
  support = 20,
  points = NULL,
  mc = NULL,
  FUN = "median",
  times = NULL,
  parameters = NULL,
  ...
)
```

Arguments

`x`	An object for which a method exists
`data`	Optional `data.frame` that was used to train the model.
`reference.var`	Character vector, referring to the (independent) reference variable or variables for which partial dependence is calculated. Providing two (or more) variables allows for probing interactions, but note that this is computationally expensive.
`support`	Integer. Number of grid points for interpolating the `reference.var`. Alternatively, use `points` for one or more variables named in `reference.var`.
`points`	Named list, with elements corresponding to `reference.var` . Use this argument to provide specific points for which to obtain marginal dependence values; for example, the mean and +/- 1SD of `reference.var`.
`mc`	Integer. If `mc` is not `NULL`, the function will sample `mc` number of rows from `data` with replacement, to estimate marginal dependency using Monte Carlo integration. This is less computationally expensive.
`FUN`	Character string with function used to integrate predictions across all elements of `x`.
`times`	Numeric matrix, representing the factor loadings of a latent growth model, with columns equal to the number of growth `parameters`, and rows equal to the number of measurement occasions.

`parameters`	Character vector of the names of the growth parameters; defaults to `NULL`, which assumes that the growth parameters are the only parameters and are in the correct order.
`...`	Extra arguments passed to `FUN`.

Author(s)

Caspar J. Van Lissa

`plotParDiffForest` *Plot parameter differences*

Description

Visualizes parameter differences between post-split nodes in a forest with boxplots.

Usage

```
plotParDiffForest(
  forest,
  plot = "boxplot",
  measure = "wald",
  normalize = FALSE,
  predictors = NULL,
  title = TRUE
)
```

Arguments

`forest`	a semforest object.
`plot`	a character that specifies the plot typ. Available plot types are "boxplot" (default) and "jitter" for a jittered strip plot with mean and standard deviation.
`measure`	a character. "wald" (default) gives the squared parameter differences divided by their pooled standard errors. "test" gives the contributions of the parameters to the test statistic. "raw" gives the absolute values of the parameter differences.
`normalize`	logical value; if TRUE parameter differences of each split are divided by sum of all differences the corresponding split. Set to FALSE by default.
`predictors`	a character. Select predictors that are to be plotted.
`title`	logical value; if TRUE a title is added to the plot.

Author(s)

Manuel Arnold

`plotParDiffTree` *Plot parameter differences*

Description

Visualizes parameter differences between post-split nodes with different plot types.

Usage

```
plotParDiffTree(
  tree,
  plot = "ballon",
  measure = "wald",
  normalize = FALSE,
  title = TRUE,
  structure = FALSE
)
```

Arguments

`tree`	a semtree object.
`plot`	a character that specifies the plot typ. Available plot types are "ballon" (default), "heatmap", and "bar".
`measure`	a character. "wald" (default) gives the squared parameter differences divided by their pooled standard errors. "test" gives the contributions of the parameters to the test statistic. "raw" gives the absolute values of the parameter differences.
`normalize`	logical value; if TRUE parameter differences of each split are divided by sum of all differences the corresponding split. Set to FALSE by default.
`title`	logical value; if TRUE a title is added to the plot.
`structure`	logical value; if TRUE the structure of the tree is plotted on the right side.

Author(s)

Manuel Arnold

`plotTreeStructure` *Plot tree structure*

Description

Plots the structure of a semtree object. This function is similar to `plot.semtree`, but it does not print the parameter values in the leaf nodes and labels the leaf nodes instead.

Usage

```
plotTreeStructure(tree, type = 2, no.plot = FALSE, ...)
```

Arguments

`tree`	a semtree object.
`type`	Type of plot. See `prp` from **rpart.plot**.
`no.plot`	logical value; if TRUE structure of the tree is printed to the console.
`...`	additional arguments passed to `prp` from **rpart.plot**.

Author(s)

Manuel Arnold

`predict.semforest` *Predict method for semtree and semforest*

Description

Predict method for semtree and semforest

Usage

```
## S3 method for class 'semforest'
predict(object, data, type = "node_id", ...)
```

Arguments

`object`	Object of class `semtree` or ‘semforest‘.
`data`	New test data of class `data.frame`. If no data is provided, attempts to extract the data from the object.
`type`	Type of prediction. One of ‘c(’node_id’)‘. See Details.
`...`	further arguments passed to or from other methods.

Value

Object of class `matrix`.

Author(s)

Caspar J. van Lissa, Andreas Brandmaier

`proximity` *Compute proximity matrix*

Description

Compute a n by n matrix across all trees in a forest, where n is the number of rows in the data, reflecting the proportion of times two cases ended up in the same terminal node of a tree.

Usage

```
proximity(x, data, ...)
```

Arguments

`x`	An object for which a method exists.
`data`	A data.frame on which proximity is computed
`...`	Parameters passed to other functions.

Details

SEM Forest Case Proximity

Value

A matrix with dimensions [i, j] whose elements reflect the proportion of times case i and j were in the same terminal node of a tree.

Author(s)

Caspar J. Van Lissa, Andreas M. Brandmaier, John J. Prindle

References

Brandmaier, A.M., Oertzen, T. v., McArdle, J.J., & Lindenberger, U. (2013). Structural equation model trees. *Psychological Methods*, 18(1), 71-86.

See Also

`semforest`, `semtree`

Examples

```
nodeids <- structure(c(9, 3, 5, 7, 10, 4, 6, 8, 9, 3, 5, 7, 10, 4, 6, 8),
.Dim = c(4L, 4L))
class(nodeids) <- "semforest_node_id"
sims <- proximity(nodeids)
dd <- as.dist(1-sims)
hc <- hclust(dd)
groups <- cutree(hc, 2)
```

`prune` *Prune a SEM Tree or SEM Forest*

Description

Returns a new tree with a maximum depth selected by the user. can be used in conjunction with plot commands to view various pruning levels.

Usage

```
prune(object, ...)
```

Arguments

`object`	A `semtree` or semforest object.
`...`	Optional parameters, such as `max.depth` the maximum depth of each tree, or also `num.trees` when pruning a forest.

Details

The returned tree is only modified by the number of levels for the tree. This function does not reevaluate the data, but provides alternatives to reduce tree complexity. If the user would like to alter the tree by increasing depth, then max.depth option must be adjusted in the `semtree.control` object (provided further splits are able to be computed).

Value

Returns a `semtree` object.

Author(s)

Andreas M. Brandmaier, John J. Prindle

References

Brandmaier, A.M., Oertzen, T. v., McArdle, J.J., & Lindenberger, U. (2013). Structural equation model trees. *Psychological Methods*, 18(1), 71-86.

See Also

`semtree`, `semtree.control`

`se` *SEMtrees Parameter Estimates Standard Error Table*

Description

Returns a table of standard errors with columns corresponding to freely estimated standard errors and rows corresponding to nodes in the tree.

Usage

```
se(tree, leafs.only = TRUE)
```

Arguments

`tree`	A SEMtree object obtained from `semtree`
`leafs.only`	Default = TRUE. Only the terminal nodes (leafs) are printed. If set to FALSE, all node standard errors are written to the `data.frame`.

Details

The row names of the resulting data frame correspond to internal node ids and the column names correspond to standard errors in the SEM. Parameter estimates can be obtained from `parameters`.

Value

Returns a `data.frame` with rows for parameters and columns for terminal nodes.

Author(s)

Andreas M. Brandmaier, John J. Prindle

References

Brandmaier, A.M., Oertzen, T. v., McArdle, J.J., & Lindenberger, U. (2013). Structural equation model trees. *Psychological Methods*, 18(1), 71-86.

See Also

`semtree`, `semtree.control`, `parameters`

`semforest` *Create a SEM Forest*

Description

Grows a SEM Forest from a template model and a dataset. This may take some time.

Usage

```
semforest(
  model,
  data,
  control = NULL,
  predictors = NULL,
  constraints = NULL,
  ...
)
```

Arguments

`model`	A template SEM. Same as in `semtree`.
`data`	A dataframe to create a forest from. Same as in `semtree`.
`control`	A semforest control object to set forest parameters.
`predictors`	An optional list of covariates. See semtree code example.
`constraints`	An optional list of covariates. See semtree code example.
`...`	Optional parameters.

Value

A semforest object.

Author(s)

Andreas M. Brandmaier, John J. Prindle

References

Brandmaier, A.M., Prindle, J. J., McArdle, J. J., & Lindenberger, U. (2016). Theory-guided exploration with structural equation model forests. *Psychological Methods*, 21(4), 566–582.

Brandmaier, A.M., Oertzen, T. v., McArdle, J.J., & Lindenberger, U. (2013). Structural equation model trees. *Psychological Methods*, 18(1), 71–86.

See Also

`semtree`

`semforest.control` *SEM Forest Control Object*

Description

A SEM Forest control object to tune parameters of the forest learning algorithm.

Usage

```
semforest.control(
  num.trees = 5,
  sampling = "subsample",
  control = NA,
  mtry = 2,
  remove_dead_trees = TRUE
)
```

Arguments

`num.trees`	Number of trees.
`sampling`	Sampling procedure. Can be subsample or bootstrap.
`control`	A SEM Tree control object. Will be generated by default.
`mtry`	Number of subsampled covariates at each node.
`remove_dead_trees`	Remove trees from forest that had runtime errors

Author(s)

Andreas M. Brandmaier, John J. Prindle

References

Brandmaier, A.M., Oertzen, T. v., McArdle, J.J., & Lindenberger, U. (2013). Structural equation model trees. *Psychological Methods*, 18(1), 71-86.

`semtree` *SEM Tree: Recursive Partitioning for Structural Equation Models*

Description

Structural equation model (SEM) trees are a combination of SEM and decision trees (also known as classification and regression trees or recursive partitioning). SEM trees hierarchically split empirical data into homogeneous groups sharing similar data patterns with respect to a SEM by recursively selecting optimal predictors of these differences from a potentially large set of predictors.

Usage

```
semtree(
  model,
  data = NULL,
  control = NULL,
  constraints = NULL,
  predictors = NULL,
  ...
)
```

Arguments

`model`	A template model specification from **OpenMx** using the `mxModel` function or a **lavaan** model using the `lavaan` function with option fit=FALSE). Model must be syntactically correct within the framework chosen, and converge to a solution.
`data`	Data.frame used in the model creation using `mxModel` or `lavaan` are input here. Order of modeled variables and predictors is not important when providing a dataset to `semtree`.
`control`	`semtree` model specifications from `semtree.control` are input here. Any changes from the default setting can be specified here.
`constraints`	A `semtree.constraints` object setting model parameters as constrained from the beginning of the `semtree` computation. This includes options to globally or locally set equality constraints and to specify focus parameters (i.e., parameter subsets that exclusively go into the function evaluating splits). Also, options for measurement invariance testing in trees are included.
`predictors`	A vector of variable names matching variable names in dataset. If NULL (default) all variables that are in dataset and not part of the model are potential predictors. Optional function input to select a subset of the unmodeled variables to use as predictors in the `semtree` function.
`...`	Optional arguments passed to the tree growing function.

Details

Calling `semtree` with an `mxModel` or `lavaan` model creates a tree that recursively partitions a dataset such that the partitions maximally differ with respect to the model-predicted distributions. Each resulting subgroup (represented as a leaf in the tree) is represented by a SEM with a distinct set of parameter estimates.

Predictors can take on any form for the splitting algorithm to function (categorical, ordered categories, continuous). Care must be taken in choosing how many predictors to include in analyses because as the number of categories grows for unordered categorical variables, the number of multigroup comparisons increases exponentially for unordered categories.

Currently available evaluation methods for assessing partitions:

1. "naive" selection method compares all possible split values to one another over all predictors included in the dataset.

2. "fair" selection uses a two step procedure for analyzing split values on predictors at each node of the tree. The first phase uses half of the sample to examine the model improvement for each split

value on each predictor, and retains the the value that presents the largest improvement for each predictor. The second phase then evaluates these best split points for each predictor on the second half of the sample. The best improvement for the c splits tested on c predictors is selected for the node and the dataset is split from this node for further testing.

3. "score" uses score-based test statistics. These statistics are much faster than the classic SEM tree approach while having favorable statistical properties.

All other parameters controlling the tree growing process are available through a separate `semtree.control` object.

Value

A `semtree` object is created which can be examined with `summary`, `plot`, and `print`.

Author(s)

Andreas M. Brandmaier, John J. Prindle, Manuel Arnold

References

Brandmaier, A.M., Oertzen, T. v., McArdle, J.J., & Lindenberger, U. (2013). Structural equation model trees. *Psychological Methods*, 18(1), 71-86.

Arnold, M., Voelkle, M. C., & Brandmaier, A. M. (2021). Score-guided structural equation model trees. *Frontiers in Psychology*, 11, Article 564403. https://doi.org/10.3389/fpsyg.2020.564403

See Also

`semtree.control`, `summary.semtree`, `parameters`, `se`, `prune.semtree`, `subtree`, `OpenMx`, `lavaan`

`semtree.constraints` *SEM Tree Constraints Object*

Description

A SEM Tree constraints object holds information regarding specifics on how the tree is grown (similar to the control object). The SEM tree control object holds all information that is independent of a specific model whereas the constraints object holds information that is specific to a certain model (e.g., specifies differential treatment of certain parameters, e.g., by holding them constant across the forest).

Usage

```
semtree.constraints(
  local.invariance = NULL,
  global.invariance = NULL,
  focus.parameters = NULL
)
```

Arguments

`local.invariance`	Vector of parameter names that are locally equal, that is, they are assumed to be equal when assessing a local split but allowed to differ subsequently.
`global.invariance`	Vector of parameter names that are globally equal, that is, estimated only once and then fixed in the tree.
`focus.parameters`	Vector of parameter names that exclusively are evaluated for between-group differences when assessing split candidates. If NULL all parameters add to the difference.

Author(s)

Andreas M. Brandmaier, John J. Prindle

References

Brandmaier, A.M., Oertzen, T. v., McArdle, J.J., & Lindenberger, U. (2013). Structural equation model trees. *Psychological Methods*, 18(1), 71-86.

See Also

semtree

`semtree.control` *SEM Tree Control Object*

Description

A `semtree.control` object contains parameters that determine the tree growing process. These parameters include choices of different split candidate selection procedures and hyperparameters of those. Calling the constructor without parameters creates a default control object. A number of tree growing methods are included in with this package: 1. ’naive’ splitting takes the best split value of all possible splits on each covariate. 2. ’fair’ selection is so called because it tests all splits on half of the data, then tests the best split value for each covariate on the other half of the data. The equal footing of each covariate in this two phase test removes bias from testing variables with many possible splits compared to those with few. 3. "fair3" does the phases described above, with an additional step of retesting all of the split values on the best covariate found in the second phase. Variations in the sample from subsetting are removed and bias in split selection further reduced. 4. ’score’ implements modern score-based statistics.

Usage

```
semtree.control(
  method = c("naive", "score", "fair", "fair3"),
  min.N = NULL,
  max.depth = NA,
  alpha = 0.05,
  alpha.invariance = NA,
  folds = 5,
  exclude.heywood = TRUE,
  progress.bar = TRUE,
  verbose = FALSE,
  bonferroni = FALSE,
  use.all = FALSE,
  seed = NA,
  custom.stopping.rule = NA,
  mtry = NA,
  report.level = 0,
  exclude.code = NA,
  linear = TRUE,
  min.bucket = NULL,
  missing = "ignore",
  use.maxlr = FALSE,
  strucchange.from = 0.15,
  strucchange.to = NULL,
  strucchange.nrep = 50000,
  refit = TRUE,
  ctsem_sd = FALSE,
  loglik = c("default", "model", "mvn")
)
```

Arguments

`method`	Default: 'naive'. One out of `c("score","fair","naive")` for either an unbiased two-step selection algorithm, a naive take-the-best, or a score-based testing scheme.
`min.N`	Default: 10. Minimum sample size per a node, used to determine whether to continue splitting a tree or establish a terminal node.
`max.depth`	Default: NA. Maximum levels per a branch. Parameter for limiting tree growth.
`alpha`	Default: 0.05. Significance level for splitting at a given node.
`alpha.invariance`	Default: NA. Significance level for invariance tests. If NA, the value of alpha is used.
`folds`	Default: 5. Defines the number of folds for the `"cv"` method.
`exclude.heywood`	Default: TRUE. Reports whether there is an identification problem in the covariance structure of an SEM tested.
`progress.bar`	Default: NA. Option to disable the progress bar for tree growth.

`verbose`	Default: FALSE. Option to turn on or off *all* model messages during tree growth.
`bonferroni`	Default: FALSE. Correct for multiple tests with Bonferroni type correction. p-values are adjusted for the number of variables tested.
`use.all`	Treatment of missing variables. By default, missing values stay in a decision node. If TRUE, cases are distributed according to a maximum likelihood principle to the child nodes.
`seed`	Default: NA. Set a random number seed for repeating random fold generation in tree analysis.
`custom.stopping.rule`	Default: NA. Otherwise, this can be a boolean function with a custom stopping rule for tree growing.
`mtry`	Default: NA. Number of sample columns to use in SEMforest analysis.
`report.level`	Default: 0. Values up to 99 can be used to increase the number of onscreen reports for semtree analysis.
`exclude.code`	Default: NA. NPSOL error code for exclusion from model fit evaluations when finding best split. Default: Models with errors during fitting are retained.
`linear`	If TRUE (default), the structural equation model is assumed to not contain any nonlinear parameter constraints and scores are computed analytically, resulting in a shorter runtime. Only relevant for models fitted with OpenMx.
`min.bucket`	Minimum bucket size. This is the minimum size any node must have, such that a given split is considered valid. Minimum bucket size is a lower bound to the sample size in the terminal nodes of a tree.
`missing`	Missing value treatment. Default is ignore
`use.maxlr`	Use MaxLR statistic for split point selection (as proposed by Arnold et al., 2021). This corrects the bias in the LR statistics incurred by testing multiple split points within one variable.
`strucchange.from`	Strucchange argument. See their package documentation.
`strucchange.to`	Strucchange argument. See their package documentation.
`strucchange.nrep`	Strucchange argument. See their package documentation.
`refit`	If TRUE (default) the initial model is fitted on the data provided to `semtree`.
`ctsem_sd`	If FALSE (default) no standard errors of CT model parameters are computed. Requesting standard errors increases runtime.
`loglik`	Character. Algorithm to compute log likelihood. The 'default' algorithm depends on the chosen SEM package. It is 'mvn' for lavaan and 'model' for all other packages. 'model'refers to a model-based computation. This is preferable because it is more general. As an alternative, 'mvn' computes the log likelihood based on the multivariate normal density and the model-implied mean and covariance matrix.

Value

A control object containing a list of the above parameters.

Author(s)

Andreas M. Brandmaier, John J. Prindle, Manuel Arnold

References

Brandmaier, A.M., Oertzen, T. v., McArdle, J.J., & Lindenberger, U. (2013). Structural equation model trees. *Psychological Methods*, 18(1), 71-86.

Arnold, M., Voelkle, M. C., & Brandmaier, A. M. (2021). Score-guided structural equation model trees. *Frontiers in Psychology*, 11, Article 564403. https://doi.org/10.3389/fpsyg.2020.564403

See Also

`semtree`

Examples

```
# create a control object with an alpha level of 1%
my.control <- semtree.control(alpha=0.01)

# set the minimum number of cases per node to ten
my.control$min.N <- 10

# print contents of the control object
print(my.control)
```

`strip` *Retain only basic tree structure*

Description

Removes all elements of a `semforest` or `semtree` except for the tree structure and terminal node parameters. This is to reduce the heavy memory footprint of sem trees and forests.

Usage

```
strip(x, parameters = NULL)
```

Arguments

`x`	An object for which a method exists.
`parameters`	Character vector, referencing parameters in the SEM model. Defaults to `NULL`, in which case all free model parameters are returned.

Details

Objects of class `semforest` and `semtree` are very large, which complicates downstream operations such as making partial dependence plots, or using the model in interactive contexts (like Shiny apps). Running `strip` removes all elements of the model except for the tree structure and terminal node parameters. Note that some methods are no longer available for the resulting object - e.g., `varimp` requires the terminal node SEM models to compute the likelihood ratio.

Value

List

Examples

```
## Not run:
if(interactive()){
 #EXAMPLE1
 }

## End(Not run)
```

`subforest` *Creates subsets of trees from forests*

Description

Creates subsets of a forest. This can be used to subset a number of trees, e.g. from:(from+num), or to remove all null (type="nonnull") trees that were due to errors, or to randomly select a sub forest (type=random).

Usage

```
subforest(forest, num = NULL, type = "nonnull", from = 1)
```

Arguments

`forest`	A SEM Forest object.
`num`	Number of trees to select.
`type`	Either 'random' or 'nonnull' or NULL. First selects a random subset, second selects all non-null trees, third allows subsetting trees.
`from`	Starting index if type=NULL.

Author(s)

Andreas M. Brandmaier, John J. Prindle

References

Brandmaier, A.M., Oertzen, T. v., McArdle, J.J., & Lindenberger, U. (2013). Structural equation model trees. *Psychological Methods*, 18(1), 71-86.

`subtree` *SEMtree Partitioning Tool*

Description

The `subtree` function returns a tree from a selected node of the `semtree` returned tree.

Usage

```
subtree(tree, startNode = NULL, level = 0, foundNode = FALSE)
```

Arguments

`tree`	A SEMtree object obtained from `semtree`
`startNode`	Node id, which will be future root node (0 to max node number of `tree`)
`level`	Ignore. Only used internally.
`foundNode`	Ignore. Only used internally.

Details

The row names of the resulting data frame correspond to internal node ids and the column names correspond to standard errors in the SEM. Standard errors of the estimates can be obtained from `se`.

Value

Returns a `semtree` object which is a partitioned tree from the input `semtree`.

Author(s)

Andreas M. Brandmaier, John J. Prindle

References

Brandmaier, A.M., Oertzen, T. v., McArdle, J.J., & Lindenberger, U. (2013). Structural equation model trees. *Psychological Methods*, 18(1), 71-86.

See Also

`semtree`, `semtree.control`

`toTable` *Tabular Representation of a SEM Tree*

Description

Converts a tree into a tabular representation. This may be useful as a textual representation for use in manuscripts.

Usage

```
toTable(tree, added.param.cols = NULL, round.param = NULL)
```

Arguments

`tree`	A SEM Tree object.
`added.param.cols`	String. Add extra columns with parameter estimates. Pass a vector with the names of the parameters that should be rendered in the table.
`round.param`	Integer. Number of digits to round parameter estimates. Default is no rounding (NULL)

Author(s)

Andreas M. Brandmaier

References

Brandmaier, A. M., Ram, N., Wagner, G. G., & Gerstorf, D. (in press). Terminal decline in well-being: The role of multi-indicator constellations of physical health and psychosocial correlates. *Developmental Psychology*.

`varimp` *SEM Forest Variable Importance*

Description

A function to calculate relative variable importance for selecting node splits over a `semforest` object.

Usage

```
varimp(
  forest,
  var.names = NULL,
  verbose = F,
  eval.fun = evaluateTree,
  method = "permutation",
  conditional = FALSE,
  ...
)
```

Arguments

`forest`	A `semforest` object
`var.names`	Covariates used in the forest creation process. NULL value will be automatically filled in by the function.
`verbose`	Boolean to print messages while function is running.
`eval.fun`	Default is `evaluateTree` function. The value of the -2LL of the leaf nodes is compared to baseline overall model.
`method`	Experimental. Some alternative methods to compute importance. Default is "permutation".
`conditional`	Conditional variable importance if TRUE, otherwise marginal variable importance.
`...`	Optional arguments.

Author(s)

Andreas M. Brandmaier, John J. Prindle

References

Brandmaier, A.M., Oertzen, T. v., McArdle, J.J., & Lindenberger, U. (2013). Structural equation model trees. *Psychological Methods*, 18(1), 71-86.

Index