Package 'PCMBase'

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Type Package

Title Simulation and Likelihood Calculation of Phylogenetic Comparative Models

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Description Phylogenetic comparative methods represent models of continuous trait data associated with the tips of a phylogenetic tree. Examples of such models are Gaussian continuous time branching stochastic processes such as Brownian motion (BM) and Ornstein-Uhlenbeck (OU) processes, which regard the data at the tips of the tree as an observed (final) state of a Markov process starting from an initial state at the root and evolving along the branches of the tree. The PCMBase R package provides a general framework for manipulating such models. This framework consists of an application programming interface for specifying data and model parameters, and efficient algorithms for simulating trait evolution under a model and calculating the likelihood of model parameters for an assumed model and trait data. The package implements a growing collection of models, which currently includes BM, OU, BM/OU with jumps, two-speed OU as well as mixed Gaussian models, in which different types of the above models can be associated with different branches of the tree. The PCMBase package is limited to trait-simulation and likelihood calculation of (mixed) Gaussian phylogenetic models. The PCMFit package provides functionality for inference of these models to tree and trait data. The package web-site <https://venelin.github.io/PCMBase/> provides access to the documentation and other resources.

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`Args_MixedGaussian_MGPMDefaultModelTypes`

Arguments to be passed to the constructor MixedGaussian when constructing a MGPM model with some of the default MGPM model types.

Description

Arguments to be passed to the constructor MixedGaussian when constructing a MGPM model with some of the default MGPM model types.

Usage

```
Args_MixedGaussian_MGPMDefaultModelTypes(omitGlobalSigmae_x = TRUE)
```

Arguments

`omitGlobalSigmae_x`	logical, indicating if the returned list should specify the global Sigmae_x parameter as '_Omitted'. Default: TRUE.

Value

a list of named arguments. Currently only a named element Sigmae_x with specification depending on `omitGlobalSigmae_x`.

See Also

MGPMDefaultModelTypes

`Args_MixedGaussian_MGPMScalarOUType` *Arguments for the MixedGaussian constructor for scalar OU MGPM models.*

Description

Arguments for the MixedGaussian constructor for scalar OU MGPM models.

Usage

```
Args_MixedGaussian_MGPMScalarOUType()
```

Value

a list.

`Args_MixedGaussian_MGPMSurfaceOUType` *Arguments for the MixedGaussian constructor for SURFACE OU MGPM models.*

Description

Arguments for the MixedGaussian constructor for SURFACE OU MGPM models.

Usage

```
Args_MixedGaussian_MGPMSurfaceOUType()
```

Value

a list.

`as.MixedGaussian` *Convert a* `GaussianPCM` *model object to a* `MixedGaussian` *model object*

Description

Convert a `GaussianPCM` model object to a `MixedGaussian` model object

Usage

```
as.MixedGaussian(o, modelTypes = NULL)
```

Arguments

`o`	an R object: either a `GaussianPCM` or a `MixedGaussian`.
`modelTypes`	NULL (the default) or a (possibly named) character string vector. Each such string denotes a mixed Gaussian regime model class, e.g. the result of calling `MGPMDefaultModelTypes()`. If specified, an attempt is made to match the deduced Gaussian regime model type from `o` with the elements of `modelTypes` and an error is raised if the match fails. If the match succeeds the converted MixedGaussian object will have the specified `modelTypes` parameter as an attribute `"modelTypes"`.

Value

a `MixedGaussian` object.

Examples

```
mg <- as.MixedGaussian(PCMBaseTestObjects$model.ab.123.bSigmae_x)
stopifnot(
  PCMLik(
    X = PCMBaseTestObjects$traits.ab.123,
    PCMBaseTestObjects$tree.ab,
    PCMBaseTestObjects$model.ab.123.bSigmae_x) ==
  PCMLik(
    X = PCMBaseTestObjects$traits.ab.123,
    PCMBaseTestObjects$tree.ab,
    mg))
```

`dataFig3` *Data for Fig3 in the TPB manuscript*

Description

A list containing simulated tree, models and data used in Fig. 3

Usage

```
dataFig3
```

Format

This is a list containing the following named elements representing simulation parameters, a simulated tree and PCM objects, used in Fig. 3. For details on all these objects, read the file data-raw/Fig3.Rmd.

`FormatCellAsLatex` *Latex representation of a model parameter or other found in a data.table object*

Description

Latex representation of a model parameter or other found in a data.table object

Usage

```
FormatCellAsLatex(x)
```

Arguments

`x`	an R object. Currently, character vectors of length 1, numeric vectors and matrices are supported.

Value

a character string

`FormatTableAsLatex` *Latex representation of a data.table with matrix and vectors in its cells*

Description

Latex representation of a data.table with matrix and vectors in its cells

Usage

```
FormatTableAsLatex(x, argsXtable = list(), ...)
```

Arguments

`x`	a data.table
`argsXtable`	a list (empty list by default) passed to xtable...
`...`	additional arguments passed to print.xtable.

Value

a character string representing a parseable latex text.

Examples

```
dt <- data.table::data.table(
   A = list(
         matrix(c(2, 0, 1.2, 3), 2, 2),
         matrix(c(2.1, 0, 1.2, 3.2, 1.3, 3.4), 3, 2)),
   b = c(2.2, 3.1))
print(FormatTableAsLatex(dt))
```

`is.GaussianPCM` *Check if an object is a ‘GaussianPCM‘*

Description

Check if an object is a ‘GaussianPCM‘

Usage

```
is.GaussianPCM(x)
```

Arguments

`x`	any object

Value

TRUE if x inherits from the S3 class ‘GaussianPCM‘, FALSE otherwise.

`is.MixedGaussian` *Check if an object is a ‘MixedGaussian‘ PCM*

Description

Check if an object is a ‘MixedGaussian‘ PCM

Usage

```
is.MixedGaussian(x)
```

Arguments

`x`	any object

Value

TRUE if x inherits from the S3 class ‘MixedGaussian‘, FALSE otherwise.

`is.PCM` *Check if an object is a PCM.*

Description

Check if an object is a PCM.

Usage

```
is.PCM(x)
```

Arguments

`x`	an object.

Value

TRUE if ‘x‘ inherits from the S3 class "PCM".

`is.PCMTree` *Check that a tree is a PCMTree*

Description

Check that a tree is a PCMTree

Usage

```
is.PCMTree(tree)
```

Arguments

`tree`	a tree object.

Value

a logical TRUE if ‘inherits(tree, "PCMTree")‘ is TRUE.

`MatchListMembers` *Find the members in a list matching a member expression*

Description

Find the members in a list matching a member expression

Usage

```
MatchListMembers(object, member, enclos = "?", q = "'", ...)
```

Arguments

`object`	a list containing named elements.
`member`	a member expression. Member expressions are character strings denoting named elements in a list object (see examples).
`enclos`	a character string containing the special symbol '?'. This symbol is to be replaced by matching expressions. The result of this substitution can be anything but, usually would be a valid R expression. Default: "?".
`q`	a quote symbol, Default: `"'"`.
`...`	additional arguments passed to `grep`. For example, these could be `ignore.case=TRUE` or `perl=TRUE`.

Value

a named character vector, with names corresponding to the matched member quoted expressions (using the argument q as a quote symbol), and values corresponding to the 'enclos-ed' expressions after substituting the '?'.

See Also

PCMListMembers

Examples

```
model <- PCMBaseTestObjects$model_MixedGaussian_ab
MatchListMembers(model, "Sigma_x", "diag(model?[,,1L])")
MatchListMembers(model, "S.*_x", "diag(model?[,,1L])")
MatchListMembers(model, "Sigma_x", "model?[,,1L][upper.tri(model?[,,1L])]")
MatchListMembers(model, "a$Sigma_x", "model?[,,1L][upper.tri(model?[,,1L])]")
```

MGPMScalarOUType *Class name for the scalar OU MGPM model type*

Description

Class name for the scalar OU MGPM model type

Usage

```
MGPMScalarOUType()
```

Value

a character vector of one named element (ScalarOU)

MGPMSurfaceOUType *Class name for the SURFACE OU MGPM model type*

Description

Class name for the SURFACE OU MGPM model type

Usage

```
MGPMSurfaceOUType()
```

Value

a character vector of one named element (SURFACE)

`MixedGaussian` *Create a multi-regime Gaussian model (MixedGaussian)*

Description

Create a multi-regime Gaussian model (MixedGaussian)

Usage

```
MixedGaussian(
  k,
  modelTypes,
  mapping,
  className = paste0("MixedGaussian_", do.call(paste0, as.list(mapping))),
  X0 = structure(0, class = c("VectorParameter", "_Global"), description =
    "trait values at the root"),
  ...,
 Sigmae_x = structure(0, class = c("MatrixParameter", "_UpperTriangularWithDiagonal",
    "_WithNonNegativeDiagonal", "_Global"), description =
    "Upper triangular factor of the non-phylogenetic variance-covariance")
)
```

Arguments

`k` integer specifying the number of traits.

`modelTypes, mapping`

These two arguments define the mapping between the regimes in the model and actual types of models. For convenience, different combinations are possible as explained below:

- `modelTypes` is a (possibly named) character string vector. Each such string denotes a mixed Gaussian regime model class, e.g. the result of calling `MGPMDefaultModelTypes()`. In that case `mapping` can be either an integer vector with values corresponding to indices in `modelTypes` or a character string vector. If `mapping` is a character string vector, first it is matched against `names(modelTypes)` and if the match fails either because of `names(modelTypes)` being `NULL` or because some of the entries in `mapping` are not present in `names(modelTypes)`, then an attempt is made to match `mapping` against `modelTypes`, i.e. it is assumed that `mapping` contains actual class names.
- `modelTypes` is a (possibly named) list of PCM models of `k` traits. In this case `mapping` can again be an integer vector denoting indices in `modelTypes` or a character string vector denoting names in `modelTypes`.

As a final note, `mapping` can also be named. In this case the names are assumed to be the names of the different regimes in the model. If `mapping` is not named, the regimes are named automatically as `as.character(seq_len(mapping))`. For example, if `modelTypes = c("BM", "OU")` and `mapping = c(a = 1, b = 1, c = 2, d = 1)` defines an MixedGaussian with four different regimes named 'a',

	'b', 'c', 'd', and model-types BM, BM, OU and BM, corresponding to each regime.
`className`	a character string defining a valid S3 class name for the resulting MixedGaussian object. If not specified, a className is generated using the expression `paste0("MixedGaussian_", do.call(paste0, as.list(mapping)))`.
`X0`	specification for the global vector X0 to be used by all models in the MixedGaussian.
`...`	specifications for other _Global parameters coming after X0.
`Sigmae_x`	sepcification of a _Global Sigmae_x parameter. This is used by Submodels only if they have Sigmae_x _Omitted.

Details

If X0 is not NULL it has no sense to use model-types including X0 as a parameter (e.g. use BM1 or BM3 instead of BM or BM2). Similarly if Sigmae_x is not NULL there is no meaning in using model-types including Sigmae_x as a parameter, (e.g. use OU2 or OU3 instead of OU or OU1).

Value

an object of S3 class className inheriting from MixedGaussian, GaussianPCM and PCM.

See Also

`PCMTreeGetPartNames`

`PCMModels()`

`MixedGaussianTemplate` *Create a template MixedGaussian object containing a regime for each model type*

Description

Create a template MixedGaussian object containing a regime for each model type

Usage

```
MixedGaussianTemplate(mg, modelTypes = NULL)
```

Arguments

`mg`	a MixedGaussian object or an object that can be converted to such via `as.MixedGaussian`.
`modelTypes`	a (possibly named) character string vector. Each such string denotes a mixed Gaussian regime model class, e.g. the result of calling `MGPMDefaultModelTypes()`. If specified, an attempt is made to match `PCMModelTypes(as.MixedGaussian(mg))` with the elements of `modelTypes` and an error is raised if the match fails. If not named, the model types and regimes in the resulting MixedGaussian object are named by the capital latin letters A,B,C,.... Default: `NULL`, which is interpreted as `PCMModelTypes(as.MixedGaussian(mg, NULL))`.

Value

a MixedGaussian with the same global parameter settings as for mg, the same modelTypes as `modelTypes`, and with a regime for each model type. The function will stop with an error if `mg` is not convertible to a MixedGaussian object or if there is a mismatch between the model types in `mg` and `modelTypes`.

Examples

```
mg <- MixedGaussianTemplate(PCMBaseTestObjects$model.ab.123.bSigmae_x)
mgTemplBMOU <- MixedGaussianTemplate(PCMBaseTestObjects$model.OU.BM)
```

`PCM` *Create a phylogenetic comparative model object*

Description

This is the entry-point function for creating model objects within the PCMBase framework representing a single model-type with one or several model-regimes of this type associated with the branches of a tree. For mixed Gaussian phylogenetic models, which enable multiple model-types, use the `MixedGaussian` function.

Usage

```
PCM(
  model,
  modelTypes = class(model)[1],
  k = 1L,
  regimes = 1L,
  params = NULL,
  vecParams = NULL,
  offset = 0L,
  spec = NULL,
  ...
)
```

Arguments

`model`	This argument can take one of the following forms: • a character vector of the S3-classes of the model object to be created (one model object can have one or more S3-classes, with the class PCM at the origin of the hierarchy); • an S3 object which's class inherits from the PCM S3 class. The Details section explains how these two types of input are processed.
`modelTypes`	a character string vector specifying a set (family) of model-classes, to which the constructed model object belongs. These are used for model-selection.
`k`	integer denoting the number of traits (defaults to 1).

`regimes`	a character or integer vector denoting the regimes.
`params`	NULL (default) or a list of parameter values (scalars, vectors, matrices, or arrays) or sub-models (S3 objects inheriting from the PCM class). See details.
`vecParams`	NULL (default) or a numeric vector the vector representation of the variable parameters in the model. See details.
`offset`	integer offset in vecParams; see Details.
`spec`	NULL or a list specifying the model parameters (see `PCMSpecify`). If NULL (default), the generic PCMSpecify is called on the created object of class `model`.
`...`	additional parameters intended for use by sub-classes of the PCM class.

Details

This is an S3 generic. The PCMBase package defines three methods for it:

PCM.PCM: A default constructor for any object with a class inheriting from "PCM".

PCM.character: A default PCM constructor from a character string specifying the type of model.

PCM.default: A default constructor called when no other constructor is found. When called this constructor raises an error message.

Value

an object of S3 class as defined by the argument `model`.

See Also

`MixedGaussian`

Examples

```
# a Brownian motion model with one regime
modelBM <- PCM(model = "BM", k = 2)
# print the model
modelBM

# a BM model with two regimes
modelBM.ab <- PCM("BM", k = 2, regimes = c("a", "b"))
modelBM.ab

# print a single parameter of the model (in this case, the root value)
modelBM.ab$X0

# assign a value to this parameter (note that the brackets [] are necessary
# to preserve  the parameter attributes):
modelBM.ab$X0[] <- c(5, 2)

PCMNumTraits(modelBM)
PCMNumRegimes(modelBM)
PCMNumRegimes(modelBM.ab)
```

```
# number of numerical parameters in the model
PCMParamCount(modelBM)

# Get a vector representation of all parameters in the model
PCMParamGetShortVector(modelBM)

# Limits for the model parameters:
lowerLimit <- PCMParamLowerLimit(modelBM)
upperLimit <- PCMParamUpperLimit(modelBM)

# assign the model parameters at random: this will use uniform distribution
# with boundaries specified by PCMParamLowerLimit and PCMParamUpperLimit
# We do this in two steps:
# 1. First we generate a random vector. Note the length of the vector equals PCMParamCount(modelBM)
randomParams <- PCMParamRandomVecParams(modelBM, PCMNumTraits(modelBM), PCMNumRegimes(modelBM))
randomParams
# 2. Then we load this random vector into the model.
PCMParamLoadOrStore(modelBM, randomParams, 0, PCMNumTraits(modelBM), PCMNumRegimes(modelBM), TRUE)

print(modelBM)

PCMParamGetShortVector(modelBM)

# generate a random phylogenetic tree of 10 tips
tree <- ape::rtree(10)

#simulate the model on the tree
traitValues <- PCMSim(tree, modelBM, X0 = modelBM$X0)

# calculate the likelihood for the model parameters, given the tree and the trait values
PCMLik(traitValues, tree, modelBM)

# create a likelihood function for faster processing for this specific model.
# This function is convenient for calling in optim because it recieves and parameter
# vector instead of a model object.
likFun <- PCMCreateLikelihood(traitValues, tree, modelBM)
likFun(randomParams)
```

`PCMAbCdEf` *Quadratic polynomial parameters A, b, C, d, E, f for each node*

Description

An S3 generic function that has to be implemented for every model class. This function is called by `PCMLik`.

Usage

```
PCMAbCdEf(
  tree,
  model,
  SE = matrix(0, PCMNumTraits(model), PCMTreeNumTips(tree)),
  metaI = PCMInfo(NULL, tree, model, verbose = verbose),
  verbose = FALSE
)
```

Arguments

`tree`	a phylo object with N tips.
`model`	an S3 object specifying both, the model type (class, e.g. "OU") as well as the concrete model parameter values at which the likelihood is to be calculated (see also Details).
`SE`	a k x N matrix specifying the standard error for each measurement in X. Alternatively, a k x k x N cube specifying an upper triangular k x k factor of the variance covariance matrix for the measurement error for each tip `i=1, ..., N`. When `SE` is a matrix, the k x k measurement error variance matrix for a tip `i` is calculated as `VE[, , i] <- diag(SE[, i] * SE[, i], nrow = k)`. When `SE` is a cube, the way how the measurement variance matrix for a tip `i` is calculated depends on the runtime option `PCMBase.Transpose.Sigma_x` as follows: **if** `getOption("PCMBase.Transpose.Sigma_x", FALSE) == FALSE` **(default):** VE[, , i] <- SE[, , i] %*% t(SE[, , i]) **if** `getOption("PCMBase.Transpose.Sigma_x", FALSE) == TRUE`**:** VE[, , i] <- t(SE[, , i]) %*% SE[, , i] Note that the above behavior is consistent with the treatment of the model parameters `Sigma_x`, `Sigmae_x` and `Sigmaj_x`, which are also specified as upper triangular factors. Default: `matrix(0.0, PCMNumTraits(model), PCMTreeNumTips(tree))`.
`metaI`	a list returned from a call to `PCMInfo(X, tree, model, SE)`, containing meta-data such as N, M and k. Alternatively, this can be a character string naming a function or a function object that returns such a list, e.g. the function`PCMInfo` or the function `PCMInfoCpp` from the `PCMBaseCpp` package.
`verbose`	logical indicating if some debug-messages should printed.

`PCMAddToListAttribute` *Add a value to a list-valued attribute of a member or members matching a pattern*

Description

Add a value to a list-valued attribute of a member or members matching a pattern

Usage

```
PCMAddToListAttribute(
  name,
  value,
  object,
  member = "",
  enclos = "?",
  spec = TRUE,
  inplace = TRUE,
  ...
)
```

Arguments

`name`	a character string denoting the attribute name.
`value`	the value for the attribute.
`object`	a PCM or a list object.
`member`	a member expression. Member expressions are character strings denoting named elements in a list object (see examples). Default: "".
`enclos`	a character string containing the special symbol '?'. This symbol is to be replaced by matching expressions. The result of this substitution can be anything but, usually would be a valid R expression. Default: "?".
`spec`	a logical (TRUE by default) indicating if the attribute should also be set in the corresponding member of the spec attribute (this is for PCM objects only).
`inplace`	logical (TRUE by default) indicating if the attribute should be set to the object in the current environment, or a modified object should be returned.
`...`	additional arguments passed to `MatchListMembers`.

Value

if `inplace` is `TRUE` no value is returned. Otherwise, a modified version of `object` is returned.

`PCMApplyTransformation` *Map a parametrization to its original form.*

Description

This is an S3 generic that transforms the passed argument by applying the transformation rules for its S3 class.

This is an S3 generic. See ‘PCMApplyTransformation._CholeskyFactor‘ for an example.

Usage

```
PCMApplyTransformation(o, ...)
```

Arguments

`o`	a PCM object or a parameter
`...`	additional arguments that can be used by implementing methods.

Details

This function returns the same object if it is not transformable.

Value

a transformed version of o.

See Also

`is.Transformable`

`PCMBaseIsADevRelease` *Check if the PCMBase version corresponds to a dev release*

Description

Check if the PCMBase version corresponds to a dev release

Usage

```
PCMBaseIsADevRelease()
```

Value

a logical

`PCMBaseTestObjects` *Test objects for the PCMBase package*

Description

A list containing simulated trees, trait-values and model objects for tests and examples of the PCM-Base package

Usage

```
PCMBaseTestObjects
```

Format

This is a list containing the following named elements representing parameters of BM, OU and MixedGaussian models with up to three traits and up to two regimes, model objects, simulated trees with partition of their nodes in up to two parts (corresponding to the two regimes), and trait data simulated on these trees.

a.H, b.H H matrices for OU models for regimes 'a' and 'b'.

a.Theta, b.Theta Theta vectors for OU models for regimes 'a' and 'b'.

a.Sigma_x, b.Sigma_x Sigma_x matrices for BM and OU models for regimes 'a' and 'b'.

a.Sigmae_x, b.Sigmae_x Sigmae_x matrices regimes 'a' and 'b'.

a.X0, b.X0 X0 vectors for regimes 'a' and 'b'.

H an array resulting from abind(a.H, b.H).

Theta a matrix resulting from cbind(Theta.a, Theta.b).

Sigma_x an array resulting from abind(a.Sigma_x, b.Sigma_x).

Sigmae_x an array resulting from abind(a.Sigmae_x, b.Sigmae_x).

model.a.1, model.a.2, model.a.3 univariate models with a single regime for each of 3 traits.

model.a.1.Omitted_X0 same as model.a.1 but omitting X0; suitable for nesting in an MGPM model.

model.a.123, model.b.123 single-regime 3-variate models.

model.a.123.Omitted_X0 single-regime 3-variate model with omitted X0 (suitable for nesting in an MGPM.

model.a.123.Omitted_X0__bSigmae_x same as model.a.123.Omitted_X0 but with the value of Sigmae_x copied from model.b.123.

model.a.123.Omitted_X0__Omitted_Sigmae_x same as model.a.123 but omitting X0 and Sigmae_x.

model.b.123.Omitted_X0, model.b.123.Omitted_X0__Omitted_Sigmae_x analogical to corresponding model.a.123...

model.ab.123 a two-regime 3-variate model.

model.ab.123.bSigmae_x a two-regime 3-variate model having Sigmae_x from b.Sigmae_x.

model_MixedGaussian_ab a two-regime MGPM model with a local Sigmae_x for each regime.

model_MixedGaussian_ab_globalSigmae_x a two-regime MGPM model with a global Sigmae_x.

N number of tips in simulated trees

tree_15_tips a tree of 15 tips used for testing clade extraction.

tree.a a tree with one part only (one regime)

tree.ab a tree partitioned in two parts (two regimes)

traits.a.1 trait values simulated with model.a.1.

traits.a.123 trait values simulated with model.a.123.

traits.a.2 trait values simulated with model.a.2.

traits.a.3 trait values simulated with model.a.3.

traits.ab.123 trait values simulated with model.ab.123 on tree.ab.

tree a tree of 5 tips used for examples.

X 3-trait data for 5 tips used together with tree for examples.

model.OU.BM a mixed Gaussian phylogenetic model for 3 traits and an OU and BM regime used in examples.

`PCMColorPalette` *A fixed palette of n colors*

Description

A fixed palette of n colors

Usage

```
PCMColorPalette(
  n,
  names,
  colors = structure(hcl(h = seq(15, 375, length = n + 1), l = 65, c =
    100)[seq_len(n)], names = names)
)
```

Arguments

`n`	an integer defining the number of colors in the resulting palette.
`names`	a character vector of length ‘n‘.
`colors`	a vector of n values convertible to colors. Default: `structure(hcl( h = seq(15, 375, length = n + 1), l = 65, c = 100)[seq_len(n)],names = names)`

Value

A vector of character strings which can be used as color specifications by R graphics functions.

`PCMCombineListAttribute`
Combine all member attributes of a given name into a list

Description

Combine all member attributes of a given name into a list

Usage

```
PCMCombineListAttribute(object, name)
```

Arguments

`object`	a named list object.
`name`	a character string denoting the name of the attribute.

Value

a list of attribute values

`PCMCond` *Conditional distribution of a daughter node given its parent node*

Description

An S3 generic function that has to be implemented for every model class.

Usage

```
PCMCond(
  tree,
  model,
  r = 1,
  metaI = PCMInfo(NULL, tree, model, verbose = verbose),
  verbose = FALSE
)
```

Arguments

`tree`	a phylo object with N tips.
`model`	an S3 object specifying both, the model type (class, e.g. "OU") as well as the concrete model parameter values at which the likelihood is to be calculated (see also Details).
`r`	an integer specifying a model regime
`metaI`	a list returned from a call to `PCMInfo(X, tree, model, SE)`, containing meta-data such as N, M and k. Alternatively, this can be a character string naming a function or a function object that returns such a list, e.g. the function`PCMInfo` or the function `PCMInfoCpp` from the `PCMBaseCpp` package.
`verbose`	logical indicating if some debug-messages should printed.

Value

an object of type specific to the type of model

PCMCond.GaussianPCM *Conditional distribution of a daughter node given its parent node*

Description

An S3 generic function that has to be implemented for every model class.

Usage

```
## S3 method for class 'GaussianPCM'
PCMCond(
  tree,
  model,
  r = 1,
  metaI = PCMInfo(NULL, tree, model, verbose = verbose),
  verbose = FALSE
)
```

Arguments

`tree`	a phylo object with N tips.
`model`	an S3 object specifying both, the model type (class, e.g. "OU") as well as the concrete model parameter values at which the likelihood is to be calculated (see also Details).
`r`	an integer specifying a model regime
`metaI`	a list returned from a call to `PCMInfo(X, tree, model, SE)`, containing meta-data such as N, M and k. Alternatively, this can be a character string naming a function or a function object that returns such a list, e.g. the function`PCMInfo` or the function `PCMInfoCpp` from the `PCMBaseCpp` package.
`verbose`	logical indicating if some debug-messages should printed.

Value

For GaussianPCM models, a named list with the following members:

`omega`	d
`Phi`	
`V`	

PCMCondVOU	*Variance-covariance matrix of an OU process with optional measurement error and jump at the start*

Description

Variance-covariance matrix of an OU process with optional measurement error and jump at the start

Usage

```
PCMCondVOU(
  H,
  Sigma,
  Sigmae = NULL,
  Sigmaj = NULL,
  xi = NULL,
  e_Ht = NULL,
  threshold.Lambda_ij = getOption("PCMBase.Threshold.Lambda_ij", 1e-08)
)
```

Arguments

`H`	a numerical k x k matrix - selection strength parameter.
`Sigma`	a numerical k x k matrix - neutral drift unit-time variance-covariance matrix.
`Sigmae`	a numerical k x k matrix - environmental variance-covariance matrix.
`Sigmaj`	is the variance matrix of the normal jump distribution (default is NULL).
`xi`	a vector of 0's and 1's corresponding to each branch in the tree. A value of 1 indicates that a jump takes place at the beginning of the branch. This arugment is only used if Sigmaj is not NULL. Default is NULL.
`e_Ht`	a numerical k x k matrix - the result of the matrix exponential expm(-t*H).
`threshold.Lambda_ij`	a 0-threshold for abs(Lambda_i + Lambda_j), where Lambda_i and Lambda_j are eigenvalues of the parameter matrix H. This threshold-values is used as a condition to take the limit time of the expression '(1-exp(-Lambda_ij*time))/Lambda_ij' as '(Lambda_i+Lambda_j) –> 0'. You can control this value by the global option "PCMBase.Threshold.Lambda_ij". The default value (1e-8) is suitable for branch lengths bigger than 1e-6. For smaller branch lengths, you may want to increase the threshold value using, e.g. 'options(PCMBase.Threshold.Lambda_ij=1e-6)'.

Value

a function of one numerical argument (time) and an integer indicating the branch-index that is used to check the corresponding element in xi.

PCMCreateLikelihood *Create a likelihood function of a numerical vector parameter*

Description

Create a likelihood function of a numerical vector parameter

Usage

```
PCMCreateLikelihood(
  X,
  tree,
  model,
  SE = matrix(0, PCMNumTraits(model), PCMTreeNumTips(tree)),
  metaI = PCMInfo(X, tree, model, SE),
  positiveValueGuard = Inf
)
```

Arguments

`X`	a `k x N` numerical matrix with possible `NA` and `NaN` entries. For `i=1,...,N`, the column `i` of X contains the measured trait values for species `i` (the tip with integer identifier equal to `i` in `tree`). Missing values can be either not-available (`NA`) or not existing (`NaN`). These two values are treated differently when calculating likelihoods (see `PCMPresentCoordinates`).
`tree`	a phylo object with N tips.
`model`	an S3 object specifying both, the model type (class, e.g. "OU") as well as the concrete model parameter values at which the likelihood is to be calculated (see also Details).

`SE`	a k x N matrix specifying the standard error for each measurement in X. Alternatively, a k x k x N cube specifying an upper triangular k x k factor of the variance covariance matrix for the measurement error for each tip `i=1, ..., N`. When `SE` is a matrix, the k x k measurement error variance matrix for a tip `i` is calculated as `VE[, , i] <- diag(SE[, i] * SE[, i], nrow = k)`. When `SE` is a cube, the way how the measurement variance matrix for a tip `i` is calculated depends on the runtime option `PCMBase.Transpose.Sigma_x` as follows:
	if `getOption("PCMBase.Transpose.Sigma_x", FALSE) == FALSE` **(default):** VE[, , i] <- SE[, , i] %*% t(SE[, , i])
	if `getOption("PCMBase.Transpose.Sigma_x", FALSE) == TRUE`**:** VE[, , i] <- t(SE[, , i]) %*% SE[, , i]
	Note that the above behavior is consistent with the treatment of the model parameters `Sigma_x`, `Sigmae_x` and `Sigmaj_x`, which are also specified as upper triangular factors. Default: `matrix(0.0, PCMNumTraits(model), PCMTreeNumTips(tree))`.

`metaI`	a list returned from a call to `PCMInfo(X, tree, model, SE)`, containing meta-data such as N, M and k. Alternatively, this can be a character string naming a function or a function object that returns such a list, e.g. the function`PCMInfo` or the function `PCMInfoCpp` from the `PCMBaseCpp` package.
`positiveValueGuard`	positive numerical value (default Inf), which serves as a guard for numerical error. Values exceeding this positiveGuard are most likely due to numerical error and PCMOptions()$PCMBase.Value.NA is returned instead.

Details

It is possible to specify a function for the argument metaI. This function should have three parameters (X, tree, model) and should return a metaInfo object. (see `PCMInfo`).

Value

a function of a numerical vector parameter called p returning the likelihood of X given the tree and the model with parameter values specified by p.

`PCMDefaultModelTypes` *Class names for the the default PCM and MGPM model types*

Description

Utility functions returning named character vector of the model class-names for the default model types used for PCM and MixedGaussian model construction.

Usage

```
PCMDefaultModelTypes()

MGPMDefaultModelTypes()
```

Value

Both, `PCMFDefaultModelTypes` and `MGPMDefaultModelTypes` return a character string vector with named elements (A,B,C,D,E,F) defined as follows (Mitov et al. 2019a):

A. BM (H = 0, diagonal Σ): BM, uncorrelated traits.

B. BM (H = 0, symmetric Σ): BM, correlated traits.

C. OU (diagonal H, diagonal Σ): OU, uncorrelated traits.

D. OU (diagonal H, symmetric Σ): OU, correlated traits, but simple (diagonal) selection strength matrix.

E. OU (symmetric H, symmetric Σ): An OU with nondiagonal symmetric H and nondiagonal symmetric Σ.

F. OU (asymmetric H, symmetric Σ): An OU with nondiagonal asymmetric H and nondiagonal symmetric Σ.

The only difference between the two functions is that the model types returned by `PCMFDefaultModelTypes` have a global parameter X0, while the model types returned by `MGPMFDefaultModelTypes` have an omitted parameter X0.

References

[Mitov et al. 2019a] Mitov, V., Bartoszek, K., & Stadler, T. (2019). Automatic generation of evolutionary hypotheses using mixed Gaussian phylogenetic models. Proceedings of the National Academy of Sciences of the United States of America, 35, 201813823. http://doi.org/10.1073/pnas.1813823116

See Also

Args_MixedGaussian_MGPMDefaultModelTypes

`PCMDefaultObject` *Generate a default object of a given PCM model type or parameter type*

Description

This is an S3 generic. See, e.g. 'PCMDefaultObject.MatrixParameter'.

Usage

```
PCMDefaultObject(spec, model, ...)
```

Arguments

`spec`	any object having a class attribute. The value of this object is not used, but its class is used for method-dispatch.
`model`	a PCM object used to extract attributes needed for creating a default object of class specified in `class(spec)`, such as the number of traits (k) or the regimes and the number of regimes;
`...`	additional arguments that can be used by methods.

Value

a parameter or a PCM object.

`PCMDescribe` *Human friendly description of a PCM*

Description

Human friendly description of a PCM

Usage

```
PCMDescribe(model, ...)
```

Arguments

`model`	a PCM model object
`...`	additional arguments used by implementing methods.

Details

This S3 generic function is intended to be specified for user models

Value

a character string

`PCMDescribeParameters` *Describe the parameters of a PCM*

Description

This is an S3 generic.

Usage

```
PCMDescribeParameters(model, ...)
```

Arguments

`model`	a PCM object.
`...`	additional arguments that can be used by implementing methods.

Value

a named list with character elements corresponding to each parameter.

PCMExtractDimensions — *Given a PCM or a parameter object, extract an analogical object for a subset of the dimensions (traits) in the original object.*

Description

Given a PCM or a parameter object, extract an analogical object for a subset of the dimensions (traits) in the original object.

Usage

```
PCMExtractDimensions(obj, dims = seq_len(PCMNumTraits(obj)), nRepBlocks = 1L)
```

Arguments

`obj`	a PCM or a parameter object.
`dims`	an integer vector; should be a subset or equal to `seq_len(PCMNumTraits(obj))` (the default).
`nRepBlocks`	a positive integer specifying if the specified dimensions should be replicated to obtain a higher dimensional model, where the parameter matrices are block-diagonal with blocks corresponding to dims. Default: 1L.

Details

This is an S3 generic

Value

an object of the same class as obj with a subset of obj's dimensions multiplied `nRepBlocks` times.

PCMExtractRegimes — *Given a PCM or a parameter object, extract an analogical object for a subset of the regimes in the original object.*

Description

Given a PCM or a parameter object, extract an analogical object for a subset of the regimes in the original object.

Usage

```
PCMExtractRegimes(obj, regimes = seq_len(PCMNumRegimes(obj)))
```

Arguments

`obj`	a PCM or a parameter object.
`regimes`	an integer vector; should be a subset or equal to `seq_len(PCMNumRegimes(obj))` (the default).

Details

This is an S3 generic

Value

an object of the same class as obj with a subset of obj's regimes

---

`PCMFindMethod` *Find the S3 method for a given PCM object or class-name and an S3 generic*

Description

Find the S3 method for a given PCM object or class-name and an S3 generic

Usage

```
PCMFindMethod(x, method = "PCMCond")
```

Arguments

`x`	a character string denoting a PCM S3 class name (e.g. "OU"), or a PCM object.
`method`	a character string denoting the name of an S3 generic function. Default: "PCM-Cond".

Value

a function object corresponding to the S3 method found or an error is raised if no such function is found for the specified object and method.

`PCMFixParameter` *Fix a parameter in a PCM model*

Description

Fix a parameter in a PCM model

Usage

```
PCMFixParameter(model, name)
```

Arguments

`model`	a PCM object
`name`	a character string

Value

a copy of the model with added class '_Fixed' to the class of the parameter `name`

`PCMGenerateModelTypes` *Generate default model types for given PCM base-classes*

Description

This function calls ‘PCMListParameterizations‘ or ‘PCMListDefaultParameterizations‘ and generates the corresponding ‘PCMParentClasses‘ and ‘PCMSpecify‘ methods in the global environment.

Usage

```
PCMGenerateModelTypes(
  baseTypes = list(BM = "default", OU = "default", White = "all"),
  sourceFile = NULL
)
```

Arguments

`baseTypes`	a named list with character string elements among `c("default", "all")` and names specifying base S3-class names for which the parametrizations (subclasses) will be generated. Defaults to `list(BM="default", OU = "default", White = "all")`. The element value specifies which one of ‘PCMListParameterizations‘ or ‘PCMListDefaultParameterizations‘ should be used: **"all"** for calling ‘PCMListParameterizations‘ **"default"** for calling ‘PCMListDefaultParameterizations‘

`sourceFile`	NULL or a character string indicating a .R filename, to which the automatically generated code will be saved. If NULL (the default), the generated source code is evaluated and the S3 methods are defined in the global environment. Default: NULL.

Value

This function has side effects only and does not return a value.

See Also

PCMListDefaultParameterizations

`PCMGenerateParameterizations`
Generate possible parameterizations for a given type of model

---

Description

A parameterization of a PCM of given type, e.g. OU, is a PCM-class inheriting from this type, which imposes some restrictions or transformations of the parameters in the base-type. This function generates the S3 methods responsible for creating such parameterizations, in particular it generates the definition of the methods for the two S3 generics ‘PCMParentClasses‘ and ‘PCMSpecify‘ for al parameterizations specified in the ‘tableParameterizations‘ argument.

Usage

```
PCMGenerateParameterizations(
  model,
  listParameterizations = PCMListParameterizations(model),
 tableParameterizations = PCMTableParameterizations(model, listParameterizations),
  env = .GlobalEnv,
  useModelClassNameForFirstRow = FALSE,
  sourceFile = NULL
)
```

Arguments

`model`	a PCM object.
`listParameterizations`	a list or a sublist returned by ‘PCMListParameterizations‘. Default: ‘PCMListParameterizations(model)‘.
`tableParameterizations`	a data.table containing the parameterizations to generate. By default this is generated from ‘listParameterizations‘ using a call ‘PCMTableParameterizations(model, listParameterizations)‘. If specified by the user, this parameter takes precedence over ‘listParameterizations‘ and ‘listParameterizations‘ is not used.

`env`	an environment where the method definitions will be stored. Default: 'env = .GlobalEnv'.
`useModelClassNameForFirstRow`	A logical specifying if the S3 class name of 'model' should be used as a S3 class for the model defined in the first row of 'tableParameterizations'. Default: FALSE.
`sourceFile`	NULL or a character string indicating a .R filename, to which the automatically generated code will be saved. If NULL (the default), the generated source code is evaluated and the S3 methods are defined in the global environment. Default: NULL.

Value

This function does not return a value. It only has a side effect by defining S3 methods in 'env'.

`PCMGetAttribute` *Value of an attribute of an object or values for an attribute found in its members*

Description

Value of an attribute of an object or values for an attribute found in its members

Usage

```
PCMGetAttribute(name, object, member = "", ...)
```

Arguments

`name`	attribute name.
`object`	a PCM model object or a PCMTree object.
`member`	a member expression. Member expressions are character strings denoting named elements in a list object (see examples). Default: "".
`...`	additional arguments passed to `MatchListMembers`.

Value

if member is an empty string, `attr(object, name)`. Otherwise, a named list containing the value for the attribute for each member in `object` matched by `member`.

Examples

```
PCMGetAttribute("class", PCMBaseTestObjects$model_MixedGaussian_ab)
PCMGetAttribute(
  "dim", PCMBaseTestObjects$model_MixedGaussian_ab,
  member = "$Sigmae_x")
```

PCMGetVecParamsRegimesAndModels

Get a vector of all parameters (real and discrete) describing a model on a tree including the numerical parameters of each model regime, the integer ids of the splitting nodes defining the regimes on the tree and the integer ids of the model types associated with each regime.

Description

Get a vector of all parameters (real and discrete) describing a model on a tree including the numerical parameters of each model regime, the integer ids of the splitting nodes defining the regimes on the tree and the integer ids of the model types associated with each regime.

Usage

```
PCMGetVecParamsRegimesAndModels(model, tree, ...)
```

Arguments

`model`	a PCM model
`tree`	a phylo object with an edge.part member.
`...`	additional parameters passed to methods.

Details

This is an S3 generic. In the default implementation, the last entry in the returned vector is the number of numerical parameters. This is used to identify the starting positions in the vector of the first splitting node.

Value

a numeric vector concatenating the result

PCMInfo

Meta-information about a tree and trait data associated with a PCM

Description

This function pre-processes the given tree and data in order to create meta-information used during likelihood calculation.

Usage

```
PCMInfo(
  X,
  tree,
  model,
  SE = matrix(0, PCMNumTraits(model), PCMTreeNumTips(tree)),
  verbose = FALSE,
  preorder = NULL,
  ...
)
```

Arguments

`X`	a `k x N` numerical matrix with possible `NA` and `NaN` entries. For `i=1,...,N`, the column `i` of X contains the measured trait values for species `i` (the tip with integer identifier equal to `i` in `tree`). Missing values can be either not-available (`NA`) or not existing (`NaN`). These two values are treated differently when calculating likelihoods (see `PCMPresentCoordinates`).
`tree`	a phylo object with N tips.
`model`	an S3 object specifying both, the model type (class, e.g. "OU") as well as the concrete model parameter values at which the likelihood is to be calculated (see also Details).
`SE`	a k x N matrix specifying the standard error for each measurement in X. Alternatively, a k x k x N cube specifying an upper triangular k x k factor of the variance covariance matrix for the measurement error for each tip `i=1, ..., N`. When `SE` is a matrix, the k x k measurement error variance matrix for a tip `i` is calculated as `VE[, , i] <- diag(SE[, i] * SE[, i], nrow = k)`. When `SE` is a cube, the way how the measurement variance matrix for a tip `i` is calculated depends on the runtime option `PCMBase.Transpose.Sigma_x` as follows: **if** `getOption("PCMBase.Transpose.Sigma_x", FALSE) == FALSE` **(default):** VE[, , i] <- SE[, , i] %*% t(SE[, , i]) **if** `getOption("PCMBase.Transpose.Sigma_x", FALSE) == TRUE`**:** VE[, , i] <- t(SE[, , i]) %*% SE[, , i] Note that the above behavior is consistent with the treatment of the model parameters `Sigma_x`, `Sigmae_x` and `Sigmaj_x`, which are also specified as upper triangular factors. Default: `matrix(0.0, PCMNumTraits(model), PCMTreeNumTips(tree))`.
`verbose`	logical indicating if some debug-messages should printed.
`preorder`	an integer vector of row-indices in tree$edge matrix as returned by PCMTreePreorder. This can be given for performance speed-up when several operations needing preorder are executed on the tree. Default : `NULL`.
`...`	additional arguments used by implementing methods.

Value

a named list with the following elements:

`X`	k x N matrix denoting the trait data;
`VE`	k x k x N array denoting the measurement error variance covariance matrix for each for each tip i = 1,...,N. See the parameter `SE` in `PCMLik`.
`M`	total number of nodes in the tree;
`N`	number of tips;
`k`	number of traits;
`RTree`	number of parts on the tree (distinct elements of tree$edge.part);
`RModel`	number of regimes in the model (elements of attr(model, regimes));
`p`	number of free parameters describing the model;
`r`	an integer vector corresponding to tree$edge with the regime for each branch in tree;
`xi`	an integer vector of 0's and 1's corresponding to the rows in tree$edge indicating the presence of a jump at the corresponding branch;
`pc`	a logical matrix of dimension k x M denoting the present coordinates for each node; in special cases this matrix can be edited by hand after calling PCMInfo and before passing the returned list to PCMLik. Otherwise, this matrix can be calculated in a custom way by specifying the option PCMBase.PCMPresentCoordinatesFun. See also `PCMPresentCoordinates` and `PCMOptions`.

This list is passed to `PCMLik`.

`PCMLik` *Likelihood of a multivariate Gaussian phylogenetic comparative model with non-interacting lineages*

Description

The likelihood of a PCM represents the probability density function of observed trait values (data) at the tips of a tree given the tree and the model parameters. Seen as a function of the model parameters, the likelihood is used to fit the model to the observed trait data and the phylogenetic tree (which is typically inferred from another sort of data, such as an alignment of genetic sequences for the species at the tips of the tree). The `PCMLik` function provides a common interface for calculating the (log-)likelihood of different PCMs. Below we denote by N the number of tips, by M the total number of nodes in the tree including tips, internal and root node, and by k - the number of traits.

Usage

```
PCMLik(
  X,
  tree,
  model,
  SE = matrix(0, PCMNumTraits(model), PCMTreeNumTips(tree)),
 metaI = PCMInfo(X = X, tree = tree, model = model, SE = SE, verbose = verbose),
  log = TRUE,
  verbose = FALSE
)
```

Arguments

`X`	a `k x N` numerical matrix with possible `NA` and `NaN` entries. For `i=1,...,N`, the column `i` of X contains the measured trait values for species `i` (the tip with integer identifier equal to `i` in `tree`). Missing values can be either not-available (`NA`) or not existing (`NaN`). These two values are treated differently when calculating likelihoods (see `PCMPresentCoordinates`).
`tree`	a phylo object with N tips.
`model`	an S3 object specifying both, the model type (class, e.g. "OU") as well as the concrete model parameter values at which the likelihood is to be calculated (see also Details).

`SE`	a k x N matrix specifying the standard error for each measurement in X. Alternatively, a k x k x N cube specifying an upper triangular k x k factor of the variance covariance matrix for the measurement error for each tip `i=1, ..., N`. When `SE` is a matrix, the k x k measurement error variance matrix for a tip `i` is calculated as `VE[, , i] <- diag(SE[, i] * SE[, i], nrow = k)`. When `SE` is a cube, the way how the measurement variance matrix for a tip `i` is calculated depends on the runtime option `PCMBase.Transpose.Sigma_x` as follows:
	if `getOption("PCMBase.Transpose.Sigma_x", FALSE) == FALSE` **(default):** VE[, , i] <- SE[, , i] %*% t(SE[, , i])
	if `getOption("PCMBase.Transpose.Sigma_x", FALSE) == TRUE`**:** VE[, , i] <- t(SE[, , i]) %*% SE[, , i]
	Note that the above behavior is consistent with the treatment of the model parameters `Sigma_x`, `Sigmae_x` and `Sigmaj_x`, which are also specified as upper triangular factors. Default: `matrix(0.0, PCMNumTraits(model), PCMTreeNumTips(tree))`.

`metaI`	a list returned from a call to `PCMInfo(X, tree, model, SE)`, containing metadata such as N, M and k. Alternatively, this can be a character string naming a function or a function object that returns such a list, e.g. the function`PCMInfo` or the function `PCMInfoCpp` from the `PCMBaseCpp` package.
`log`	logical indicating whether a log-likelehood should be calculated. Default is TRUE.
`verbose`	logical indicating if some debug-messages should printed.

Details

For efficiency, the argument `metaI` can be provided explicitly, because this is not supposed to change during a model inference procedure such as likelihood maximization.

Value

a numerical value with named attributes as follows:

X0 A numerical vector of length k specifying the value at the root for which the likelihood value was calculated. If the model contains a member called X0, this vector is used; otherwise the value of X0 maximizing the likelihood for the given model parameters is calculated by maximizing the quadratic polynomial 'X0 * L_root * X0 + m_root * X0 + r_root';

error A character string with information if a numerical or other logical error occurred during likelihood calculation.

If an error occured during likelihood calculation, the default behavior is to return NA with a non-NULL error attribute. This behavior can be changed in using global options:

"PCMBase.Value.NA" Allows to specify a different NA value such as `-Inf` or `-1e20` which can be used in combination with `log = TRUE` when using `optim` to maximize the log-likelihood;

"PCMBase.Errors.As.Warnings" Setting this option to FALSE will cause any error to result in calling the `stop` R-base function. If not caught in a `tryCatch`, this will cause the inference procedure to abort at the occurence of a numerical error. By default, this option is set to TRUE, which means that `getOption("PCMBase.Value.NA", as.double(NA))` is returned with an error attribute and a warning is issued.

See Also

`PCMInfo` `PCMAbCdEf` `PCMLmr` `PCMSim` `PCMCond`

Examples

```
N <- 10
tr <- PCMTree(ape::rtree(N))

model <- PCMBaseTestObjects$model_MixedGaussian_ab

PCMTreeSetPartRegimes(tr, c(`11` = 'a'), setPartition = TRUE)

set.seed(1, kind = "Mersenne-Twister", normal.kind = "Inversion")
X <- PCMSim(tr, model, X0 = rep(0, 3))

PCMLik(X, tr, model)
```

`PCMLikDmvNorm` *Calculate the likelihood of a model using the standard formula for multivariate pdf*

Description

Calculate the likelihood of a model using the standard formula for multivariate pdf

Usage

```
PCMLikDmvNorm(
  X,
  tree,
  model,
  SE = matrix(0, PCMNumTraits(model), PCMTreeNumTips(tree)),
  metaI = PCMInfo(X, tree, model, SE, verbose = verbose),
  log = TRUE,
  verbose = FALSE
)
```

Arguments

`X`	a `k x N` numerical matrix with possible `NA` and `NaN` entries. For `i=1,...,N`, the column `i` of X contains the measured trait values for species `i` (the tip with integer identifier equal to `i` in `tree`). Missing values can be either not-available (`NA`) or not existing (`NaN`). These two values are treated differently when calculating likelihoods (see `PCMPresentCoordinates`).
`tree`	a phylo object with N tips.
`model`	an S3 object specifying both, the model type (class, e.g. "OU") as well as the concrete model parameter values at which the likelihood is to be calculated (see also Details).

`SE`	a k x N matrix specifying the standard error for each measurement in X. Alternatively, a k x k x N cube specifying an upper triangular k x k factor of the variance covariance matrix for the measurement error for each tip `i=1, ..., N`. When `SE` is a matrix, the k x k measurement error variance matrix for a tip `i` is calculated as `VE[, , i] <- diag(SE[, i] * SE[, i], nrow = k)`. When `SE` is a cube, the way how the measurement variance matrix for a tip `i` is calculated depends on the runtime option `PCMBase.Transpose.Sigma_x` as follows:
	if `getOption("PCMBase.Transpose.Sigma_x", FALSE) == FALSE` **(default):** VE[, , i] <- SE[, , i] %*% t(SE[, , i])
	if `getOption("PCMBase.Transpose.Sigma_x", FALSE) == TRUE`**:** VE[, , i] <- t(SE[, , i]) %*% SE[, , i]
	Note that the above behavior is consistent with the treatment of the model parameters `Sigma_x`, `Sigmae_x` and `Sigmaj_x`, which are also specified as upper triangular factors. Default: `matrix(0.0, PCMNumTraits(model), PCMTreeNumTips(tree))`.

`metaI`	a list returned from a call to `PCMInfo(X, tree, model, SE)`, containing meta-data such as N, M and k. Alternatively, this can be a character string naming a function or a function object that returns such a list, e.g. the function`PCMInfo` or the function `PCMInfoCpp` from the `PCMBaseCpp` package.
`log`	logical indicating whether a log-likelehood should be calculated. Default is TRUE.
`verbose`	logical indicating if some debug-messages should printed.

Value

a numerical value with named attributes as follows:

`PCMLikTrace` *Tracing the log-likelihood calculation of a model over each node of the tree*

Description

This is an S3 generic function providing tracing information for the likelihood calculation for a given tree, data and model parameters. Useful for illustration or for debugging purpose.

Usage

```
PCMLikTrace(
  X,
  tree,
  model,
  SE = matrix(0, PCMNumTraits(model), PCMTreeNumTips(tree)),
  metaI = PCMInfo(X = X, tree = tree, model = model, SE = SE, verbose = verbose),
  log = TRUE,
  verbose = FALSE
)
```

Arguments

`X`	a `k x N` numerical matrix with possible `NA` and `NaN` entries. For `i=1,...,N`, the column `i` of X contains the measured trait values for species `i` (the tip with integer identifier equal to `i` in `tree`). Missing values can be either not-available (`NA`) or not existing (`NaN`). These two values are treated differently when calculating likelihoods (see `PCMPresentCoordinates`).
`tree`	a phylo object with N tips.
`model`	an S3 object specifying both, the model type (class, e.g. "OU") as well as the concrete model parameter values at which the likelihood is to be calculated (see also Details).

`SE`	a k x N matrix specifying the standard error for each measurement in X. Alternatively, a k x k x N cube specifying an upper triangular k x k factor of the variance covariance matrix for the measurement error for each tip `i=1, ..., N`. When `SE` is a matrix, the k x k measurement error variance matrix for a tip `i` is calculated as `VE[, , i] <- diag(SE[, i] * SE[, i], nrow = k)`. When `SE` is a cube, the way how the measurement variance matrix for a tip `i` is calculated depends on the runtime option `PCMBase.Transpose.Sigma_x` as follows:
	if `getOption("PCMBase.Transpose.Sigma_x", FALSE) == FALSE` **(default):** VE[, , i] <- SE[, , i] %*% t(SE[, , i])
	if `getOption("PCMBase.Transpose.Sigma_x", FALSE) == TRUE`**:** VE[, , i] <- t(SE[, , i]) %*% SE[, , i]
	Note that the above behavior is consistent with the treatment of the model parameters `Sigma_x`, `Sigmae_x` and `Sigmaj_x`, which are also specified as upper triangular factors. Default: `matrix(0.0, PCMNumTraits(model), PCMTreeNumTips(tree))`.

`metaI`	a list returned from a call to `PCMInfo(X, tree, model, SE)`, containing meta-data such as N, M and k. Alternatively, this can be a character string naming a function or a function object that returns such a list, e.g. the function`PCMInfo` or the function `PCMInfoCpp` from the `PCMBaseCpp` package.
`log`	logical indicating whether a log-likelehood should be calculated. Default is TRUE.
`verbose`	logical indicating if some debug-messages should printed.

Value

The returned object will, in general, depend on the type of model and the algorithm used for likelihood calculation. For a G_LInv model and pruning-wise likelihood calculation, the returned object will be a data.table with columns corresponding to the node-state variables, e.g. the quadratic polynomial coefficients associated with each node in the tree.

See Also

`PCMInfo` `PCMAbCdEf` `PCMLmr` `PCMSim` `PCMCond` `PCMParseErrorMessage`

`PCMListMembers` *A vector of access-code strings to all members of a named list*

Description

A vector of access-code strings to all members of a named list

Usage

```
PCMListMembers(
  l,
  recursive = TRUE,
  format = c("$", "$'", "$\"", "$`", "[['", "[[\"", "[[`")
)
```

Arguments

`l`	a named list object.
`recursive`	logical indicating if list members should be gone through recursively. TRUE by default.
`format`	a character string indicating the format for accessing a member. Acceptable values are `c("$", "$'", '$"', '$`', "[['", '[["', '[[`')` of which the first one is taken as default.

Value

a vector of character strings denoting each named member of the list.

Examples

```
PCMListMembers(PCMBaseTestObjects$model_MixedGaussian_ab)
PCMListMembers(PCMBaseTestObjects$model_MixedGaussian_ab, format = '$`')
PCMListMembers(PCMBaseTestObjects$tree.ab, format = '$`')
```

`PCMListParameterizations`
Specify the parameterizations for each parameter of a model

Description

These are S3 generics. ‘PCMListParameterizations‘ should return all possible parametrizations for the class of ‘model‘. ‘PCMListDefaultParameterizations‘ is a handy way to specify a subset of all parametrizations. ‘PCMListDefaultParameterizations‘ should be used to avoid generating too many model parametrizations which occupy space in the R-global environment while they are not used (see PCMGenerateParameterizations). It is mandatory to implement a specification for ‘PCMList-Parameterizations‘ for each newly defined class of models. ‘PCMListDefaultParameterizations‘ has a default implementation that calls ‘PCMListParameterizations‘ and returns the first parametrization for each parameter. Hence, implementing a method for ‘PCMListDefaultParameterizations‘ for a newly defined model type is optional.

Usage

```
PCMListParameterizations(model, ...)

PCMListDefaultParameterizations(model, ...)
```

Arguments

`model`	a PCM.
`...`	additional arguments used by implementing methods.

Value

a named list with list elements corresponding to each parameter in model. Each list element is a list of character vectors, specifying the possible S3 class attributes for the parameter in question. For an example, type ‘PCMListParameterizations.BM‘ to see the possible parameterizations for the BM model.

See Also

PCMGenerateParameterizations

PCMLmr *Quadratic polynomial parameters L, m, r*

Description

Quadratic polynomial parameters L, m, r

Usage

```
PCMLmr(
  X,
  tree,
  model,
  SE = matrix(0, PCMNumTraits(model), PCMTreeNumTips(tree)),
  metaI = PCMInfo(X = X, tree = tree, model = model, SE = SE, verbose = verbose),
  root.only = TRUE,
  verbose = FALSE
)
```

Arguments

X	a k x N numerical matrix with possible NA and NaN entries. For i=1,..., N, the column i of X contains the measured trait values for species i (the tip with integer identifier equal to i in tree). Missing values can be either not-available (NA) or not existing (NaN). These two values are treated differently when calculating likelihoods (see PCMPresentCoordinates).
tree	a phylo object with N tips.
model	an S3 object specifying both, the model type (class, e.g. "OU") as well as the concrete model parameter values at which the likelihood is to be calculated (see also Details).

SE	a k x N matrix specifying the standard error for each measurement in X. Alternatively, a k x k x N cube specifying an upper triangular k x k factor of the variance covariance matrix for the measurement error for each tip i=1, ..., N. When SE is a matrix, the k x k measurement error variance matrix for a tip i is calculated as VE[, , i] <- diag(SE[, i] * SE[, i], nrow = k). When SE is a cube, the way how the measurement variance matrix for a tip i is calculated depends on the runtime option PCMBase.Transpose.Sigma_x as follows:
	
	if getOption("PCMBase.Transpose.Sigma_x", FALSE) == FALSE **(default):** VE[, , i] <- SE[, , i] %*% t(SE[, , i])
	
	if getOption("PCMBase.Transpose.Sigma_x", FALSE) == TRUE**:** VE[, , i] <- t(SE[, , i]) %*% SE[, , i]
	
	Note that the above behavior is consistent with the treatment of the model parameters Sigma_x, Sigmae_x and Sigmaj_x, which are also specified as upper triangular factors. Default: matrix(0.0, PCMNumTraits(model), PCMTreeNumTips(tree)).

`metaI`	a list returned from a call to `PCMInfo(X, tree, model, SE)`, containing meta-data such as N, M and k. Alternatively, this can be a character string naming a function or a function object that returns such a list, e.g. the function`PCMInfo` or the function `PCMInfoCpp` from the `PCMBaseCpp` package.
`root.only`	logical indicating whether to return the calculated values of L,m,r only for the root or for all nodes in the tree.
`verbose`	logical indicating if some debug-messages should printed.

Value

A list with the members A,b,C,d,E,f,L,m,r for all nodes in the tree or only for the root if root.only=TRUE.

`PCMMapModelTypesToRegimes`

Integer vector giving the model type index for each regime

Description

Integer vector giving the model type index for each regime

Usage

```
PCMMapModelTypesToRegimes(model, tree, ...)
```

Arguments

`model`	a PCM model
`tree`	a phylo object with an edge.part member
`...`	additional parameters passed to methods

Details

This is a generic S3 method. The default implementation for the basic class PCM returns a vector of 1's, because it assumes that a single model type is associated with each regime. The implementation for mixed Gaussian models returns the mapping attribute of the MixedGaussian object reordered to correspond to `PCMTreeGetPartNames(tree)`.

Value

an integer vector with elements corresponding to the elements in `PCMTreeGetPartNames(tree)`

PCMMean — *Expected mean vector at each tip conditioned on a trait-value vector at the root*

Description

Expected mean vector at each tip conditioned on a trait-value vector at the root

Usage

```
PCMMean(
  tree,
  model,
  X0 = model$X0,
  metaI = PCMInfo(NULL, tree, model, verbose = verbose),
  internal = FALSE,
  verbose = FALSE
)
```

Arguments

`tree`	a phylo object with N tips.
`model`	an S3 object specifying both, the model type (class, e.g. "OU") as well as the concrete model parameter values at which the likelihood is to be calculated (see also Details).
`X0`	a k-vector denoting the root trait
`metaI`	a list returned from a call to `PCMInfo(X, tree, model, SE)`, containing meta-data such as N, M and k. Alternatively, this can be a character string naming a function or a function object that returns such a list, e.g. the function`PCMInfo` or the function `PCMInfoCpp` from the `PCMBaseCpp` package.
`internal`	a logical indicating ig the per-node mean vectors should be returned (see Value). Default FALSE.
`verbose`	logical indicating if some debug-messages should printed.

Value

If internal is FALSE (default), then a k x N matrix Mu, such that `Mu[, i]` equals the expected mean k-vector at tip i, conditioned on `X0` and the tree. Otherwise, a k x M matrix Mu containing the mean vector for each node.

Examples

```
# a Brownian motion model with one regime
modelBM <- PCM(model = "BM", k = 2)
# print the model
modelBM
```

```
# assign the model parameters at random: this will use uniform distribution
# with boundaries specified by PCMParamLowerLimit and PCMParamUpperLimit
# We do this in two steps:
# 1. First we generate a random vector. Note the length of the vector equals PCMParamCount(modelBM)
randomParams <- PCMParamRandomVecParams(modelBM, PCMNumTraits(modelBM), PCMNumRegimes(modelBM))
randomParams
# 2. Then we load this random vector into the model.
PCMParamLoadOrStore(modelBM, randomParams, 0, PCMNumTraits(modelBM), PCMNumRegimes(modelBM), TRUE)

# create a random tree of 10 tips
tree <- ape::rtree(10)
PCMMean(tree, modelBM)
```

`PCMMeanAtTime` *Calculate the mean at time t, given X0, under a PCM model*

Description

Calculate the mean at time t, given X0, under a PCM model

Usage

```
PCMMeanAtTime(
  t,
  model,
  X0 = model$X0,
  regime = PCMRegimes(model)[1L],
  verbose = FALSE
)
```

Arguments

`t`	positive numeric denoting time
`model`	a PCM model object
`X0`	a numeric vector of length k, where k is the number of traits in the model (Defaults to model$X0).
`regime`	an integer or a character denoting the regime in model for which to do the calculation; Defaults to PCMRegimes(model)[1L], meaning the first regime in the model.
`verbose`	a logical indicating if (debug) messages should be written on the console (Defaults to FALSE).

Value

A numeric vector of length k

Examples

```
# a Brownian motion model with one regime
modelBM <- PCM(model = "BM", k = 2)
# print the model
modelBM
# assign the model parameters at random: this will use uniform distribution
# with boundaries specified by PCMParamLowerLimit and PCMParamUpperLimit
# We do this in two steps:
# 1. First we generate a random vector. Note the length of the vector equals PCMParamCount(modelBM)
randomParams <- PCMParamRandomVecParams(modelBM, PCMNumTraits(modelBM), PCMNumRegimes(modelBM))
randomParams
# 2. Then we load this random vector into the model.
PCMParamLoadOrStore(modelBM, randomParams, 0, PCMNumTraits(modelBM), PCMNumRegimes(modelBM), TRUE)

# PCMMeanAtTime(1, modelBM)

# note that the variance at time 0 is not the 0 matrix because the model has a non-zero
# environmental deviation
PCMMeanAtTime(0, modelBM)
```

PCMModels *Get a list of PCM models currently implemented*

Description

Get a list of PCM models currently implemented

Usage

```
PCMModels(pattern = NULL, parentClass = NULL, ...)
```

Arguments

pattern	a character string specifying an optional for the model-names to search for.
parentClass	a character string specifying an optional parent class of the models to look for.
...	additional arguments used by implementing methods.

Details

The function is using the S3 api function `methods` looking for all registered implementations of the function `PCMSpecify`.

Value

a character vector of the model classes found.

Examples

```
PCMModels()
PCMModels("^OU")
```

`PCMModelTypes` *Get the model type(s) of a model*

Description

For a regular PCM object, the model type is its S3 class. For a MixedGaussian each regime is mapped to one of several possible model types.

Usage

```
PCMModelTypes(obj)
```

Arguments

`obj`	a PCM object

Value

a character vector

`PCMNumRegimes` *Number of regimes in a obj*

Description

Number of regimes in a obj

Usage

```
PCMNumRegimes(obj)
```

Arguments

`obj`	a PCM object

Value

an integer

PCMNumTraits *Number of traits modeled by a PCM*

Description

Number of traits modeled by a PCM

Usage

```
PCMNumTraits(model)
```

Arguments

`model`	a PCM object or an a parameter object (the name of this argument could be misleading, because both, model and parameter objects are supported).

Value

an integer

PCMOptions *Global options for the PCMBase package*

Description

Global options for the PCMBase package

Usage

```
PCMOptions()
```

Value

a named list with the currently set values of the following global options:

`PCMBase.Value.NA` NA value for the likelihood; used in GaussianPCM to return this value in case of an error occurring during likelihood calculation. By default, this is set to `as.double(NA)`.

`PCMBase.Errors.As.Warnings` a logical flag indicating if errors (occuring, e.g. during likelihood calculation) should be treated as warnings and added as an attribute "error" to attach to the likelihood values. Default TRUE.

`PCMBase.Raise.Lik.Errors` Should numerical and other sort of errors occurring during likelihood calculation be raised either as errors or as warnings, depending on the option `PCMBase.Errors.As.Warnings`. Default TRUE. This option can be useful if too frequent warnings get raised during a model fit procedure.

`PCMBase.Threshold.Lambda_ij` a 0-threshold for abs(Lambda_i + Lambda_j), where Lambda_i and Lambda_j are eigenvalues of the parameter matrix H of an OU or other model. Default 1e-8. See `PCMPExpxMeanExp`.

`PCMBase.Threshold.EV` A 0-threshold for the eigenvalues of the matrix V for a given branch. The V matrix is considered singular if it has eigenvalues smaller than `PCMBase.Threshold.EV` or when the ratio min(svdV)/max(svdV) is below `PCMBase.Threshold.SV` . Default is 1e-5. Treatment of branches with singular V matrix is defined by the option `PCMBase.Skip.Singular`.

`PCMBase.Threshold.SV` A 0-threshold for min(svdV)/max(svdV), where svdV is the vector of singular values of the matrix V for a given branch. The V matrix is considered singular if it has eigenvalues smaller than `PCMBase.Threshold.EV` or when the ratio min(svdV)/max(svdV) is below PCMBase.Threshold.SV. Default is 1e-6. Treatment of branches with singular V matrix is defined by the option `PCMBase.Skip.Singular`.

`PCMBase.Threshold.Skip.Singular` A double indicating if an internal branch of shorter length with singular matrix V should be skipped during likelihood calculation. Setting this option to a higher value, together with a TRUE value for the option PCMBase.Skip.Singular will result in tolerating some parameter values resulting in singular variance covariance matrix of the transition distribution. Default 1e-4.

`PCMBase.Skip.Singular` A logical value indicating whether internal branches with singular matrix V and shorter than `getOption("PCMBase.Threshold.Skip.Singular")` should be skipped during likelihood calculation, adding their children L,m,r values to their parent node. Default TRUE. Note, that setting this option to FALSE may cause some models to stop working, e.g. the White model. Setting this option to FALSE will also cause errors or NA likelihood values in the case of trees with very short or 0-length branches.

`PCMBase.Tolerance.Symmetric` A double specifying the tolerance in tests for symmetric matrices. Default 1e-8; see also `isSymmetric`.

`PCMBase.Lmr.mode` An integer code specifying the parallel likelihood calculation mode.

`PCMBase.ParamValue.LowerLimit` Default lower limit value for parameters, default setting is -10.0.

`PCMBase.ParamValue.LowerLimit.NonNegative` Numeric (default: 0.0) indication the lower limit for parameters inheriting from class `'_NonNegative'`s

`PCMBase.ParamValue.LowerLimit.NonNegativeDiagonal` Default lower limit value for parameters corresponding to non-negative diagonal elements of matrices, default setting is 0.0.

`PCMBase.ParamValue.UpperLimit` Default upper limit value for parameters, default setting is 10.0.

`PCMBase.Transpose.Sigma_x` Should upper diagonal factors for variance-covariance rate matrices be transposed, e.g. should Sigma = t(Sigma_x) Sigma_x or, rather Sigma = Sigma_x t(Sigma_x)? Note that the two variants are not equal. The default is FALSE, meaning Sigma = Sigma_x t(Sigma_x). In this case, Sigma_x is not the actual upper Cholesky factor of Sigma, i.e. chol(Sigma) != Sigma_x. See also `chol` and `UpperTriFactor`. This option applies to parameters Sigma_x, Sigmae_x, Sigmaj_x and the measurement errors `SE[,,i]` for each measurement i when the argument `SE` is specified as a cube.

`PCMBase.MaxLengthListCladePartitions` Maximum number of tree partitions returned by `PCMTreeListCladePartitio` This option has the goal to interrupt the recursive search for new partitions in the case of calling PCMTreeListCladePartitions on a big tree with a small value of the maxCladeSize argument. By default this is set to Inf.

`PCMBase.PCMPresentCoordinatesFun` A function with the same synopsis as `PCMPresentCoordinates` that can be specified in case of custom setting for the present coordinates for specific nodes of the tree. See `PCMPresentCoordinates`, and `PCMInfo`.

`PCMBase.Use1DClasses` Logical indicating if 1D arithmetic operations should be used instead of multi-dimensional ones. This can speed-up computations in the case of a single trait. Currently, this feature is implemented only in the PCMBaseCpp R-package and only for some model types, such as OU and BM. Default: FALSE

`PCMBase.PrintSubscript_u` Logical indicating if a subscript 'u' should be printed instead of a subscript 'x'. Used in `PCMTable`. Default: FALSE.

`PCMBase.MaxNForGuessSigma_x` A real fraction number in the interval (0, 1) or an integer bigger than 1 controlling the number of tips to use for analytical calculation of the evolutionary rate matrix under a BM assumption. This option is used in the suggested PCMFit R-package. Default: 0.25.

`PCMBase.UsePCMVarForVCV` Logical (default: FALSE) indicating if the function `PCMTreeVCV` should use `PCMVar` instead of ape's function `vcv` to calculate the phylogenetic variance covariance matrix under BM assumption. Note that setting this option to TRUE would slow down the function PCMTreeVCV considerably but may be more stable, particularly in the case of very big and deep trees, where previous ape's versions of the `vcv` function have thrown stack-overflow errors.

Examples

```
PCMOptions()
```

`PCMPairSums` *Sums of pairs of elements in a vector*

Description

Sums of pairs of elements in a vector

Usage

```
PCMPairSums(lambda)
```

Arguments

`lambda`	a numeric vector

Value

a squared symmetric matrix with elem_ij=lambda_i+lambda_j.

`PCMParam` *Module PCMParam*

Description

Global and S3 generic functions for manipulating model parameters. The parameters in a PCM are named objects with a class attribute specifying the main type and optional properties (tags).

S3 generic functions:

PCMParamCount() Counting the number of actual numeric parameters (used, e.g. for calculating information scores, e.g. AIC);

PCMParamLoadOrStore(), PCMParamLoadOrStore() Storing/loading a parameter to/from a numerical vector;

PCMParamLowerLimit(),PCMParamUpperLimit() Specifying parameter upper and lower limits;

PCMParamRandomVecParams() Generating a random parameter vector;

For all the above properties, check-functions are defined, e.g. ‘is.Local(o)‘, ‘is.Global(o)‘, ‘is.ScalarParameter(o)‘, ‘is.VectorParameter‘, etc.

`PCMParamBindRegimeParams` *Bind named vectors or matrices into an array so that the names form the names of the last dimension.*

Description

Bind named vectors or matrices into an array so that the names form the names of the last dimension.

Usage

```
PCMParamBindRegimeParams(...)
```

Arguments

`...`	Any number of named vectors, or matrices. The dimensions of all the arrays must match. The names will be used for the names of the regimes.

Value

an array with dim attribute one longer than the number of dimensions of each argument, i.e. if there are 5 vector arguments of length 2, the returned value will be an array with dim c(2,5); if there are 5 matrix arguments of dim 2 x 2, the returned value will be an array with dim c(2,2,5).

Examples

```
# regimes

# in regime 'a' the three traits evolve according to three independent OU processes
a.X0 <- c(5, 2, 1)
a.H <- rbind(
  c(0, 0, 0),
  c(0, 2, 0),
  c(0, 0, 3))
a.Theta <- c(10, 6, 2)
a.Sigma_x <- rbind(
  c(1.6, 0.0, 0.0),
  c(0.0, 2.4, 0.0),
  c(0.0, 0.0, 2.0))
a.Sigmae_x <- rbind(
  c(0.0, 0.0, 0.0),
  c(0.0, 0.0, 0.0),
  c(0.0, 0.0, 0.0))
a.h_drift<-c(0, 0, 0)

# in regime 'b' there is correlation between the traits
b.X0 <- c(12, 4, 3)
b.H <- rbind(
  c(2.0, 0.1, 0.2),
  c(0.1, 0.6, 0.2),
  c(0.2, 0.2, 0.3))
b.Theta <- c(10, 6, 2)
b.Sigma_x <- rbind(
  c(1.6, 0.3, 0.3),
  c(0.0, 0.3, 0.4),
  c(0.0, 0.0, 2.0))
b.Sigmae_x <- rbind(
  c(0.2, 0.0, 0.0),
  c(0.0, 0.3, 0.0),
  c(0.0, 0.0, 0.4))
b.h_drift<-c(1, 2, 3)

H <- PCMParamBindRegimeParams(a = a.H, b = b.H)
Theta <- PCMParamBindRegimeParams(a = a.Theta, b = b.Theta)
Sigma_x <- PCMParamBindRegimeParams(a = a.Sigma_x, b = b.Sigma_x)
Sigmae_x <- PCMParamBindRegimeParams(a = a.Sigmae_x, b = b.Sigmae_x)
h_drift <- PCMParamBindRegimeParams(a = a.h_drift, b = b.h_drift)

model.a.BM_drift.123 <- PCM("BM_drift", k = 3, regimes = "a",
params = list(
  X0 = a.X0,
  h_drift = h_drift[,'a',drop=FALSE],
  Sigma_x = Sigma_x[,,'a',drop=FALSE],
  Sigmae_x = Sigmae_x[,,'a',drop=FALSE]))

# regimes 'a' and 'b', traits 1, 2 and 3
model.ab.123 <- PCM("OU", k = 3, regimes = c("a", "b"),
                    params = list(
                      X0 = a.X0,
                      H = H[,,,drop=FALSE],
                      Theta = Theta[,,drop=FALSE],
                      Sigma_x = Sigma_x[,,,drop=FALSE],
                      Sigmae_x = Sigmae_x[,,,drop=FALSE]))
```

`PCMParamCount` *Count the number of free parameters associated with a PCM or a PCM-parameter*

Description

Count the number of free parameters associated with a PCM or a PCM-parameter

Usage

```
PCMParamCount(
  o,
  countRegimeChanges = FALSE,
  countModelTypes = FALSE,
  offset = 0L,
  k = 1L,
  R = 1L,
  parentModel = NULL
)
```

Arguments

`o`	a PCM model object or a parameter of a PCM object
`countRegimeChanges`	logical indicating if regime changes should be counted. If TRUE, the default implementation would add `PCMNumRegimes(model) - 1`. Default FALSE.
`countModelTypes`	logical indicating whether the model type should be counted. If TRUE the default implementation will add +1 only if there are more than one modelTypes (`length(attr(model, "modelTypes", exact = TRUE)) > 1`), assuming that all regimes are regimes of the same model type (e.g. OU). The implementation for MRG models will add +1 for every regime if there are more than one modelTypes. Default FALSE.
`offset`	an integer denoting an offset count from which to start counting (internally used). Default: 0.
`k`	an integer denoting the number of modeled traits. Default: 1.
`R`	an integer denoting the number of regimes in the model. Default: 1.
`parentModel`	NULL or a PCM object. Default: NULL.

Value

an integer

`PCMParamGetShortVector` *Get a vector of the variable numeric parameters in a model*

Description

The short vector of the model parameters does not include the nodes in the tree where a regime change occurs, nor the the model types associated with each regime.

Usage

```
PCMParamGetShortVector(o, k = 1L, R = 1L, ...)
```

Arguments

`o`	a PCM model object or a parameter of a PCM object
`k`	an integer denoting the number of modeled traits. Default: 1.
`R`	an integer denoting the number of regimes in the model. Default: 1.
`...`	other arguments that could be used by implementing methods.

Value

a numeric vector of length equal to ‘PCMParamCount(o, FALSE, FALSE, 0L, k, R)‘.

`PCMParamLoadOrStore` *Load (or store) a PCM parameter from (or to) a vector of the variable parameters in a model.*

Description

Load (or store) a PCM parameter from (or to) a vector of the variable parameters in a model.

Usage

```
PCMParamLoadOrStore(o, vecParams, offset, k, R, load, parentModel = NULL)
```

Arguments

`o`	a PCM model object or a parameter of a PCM object
`vecParams`	a numeric vector.
`offset`	an integer denoting an offset count from which to start counting (internally used). Default: 0.
`k`	an integer denoting the number of modeled traits. Default: 1.
`R`	an integer denoting the number of regimes in the model. Default: 1.
`load`	logical indicating if parameters should be loaded from vecParams into o (TRUE) or stored to vecParams from o (FALSE).
`parentModel`	NULL or a PCM object. Default: NULL.

Details

This S3 generic function has both, a returned value and side effects.

Value

an integer equaling the number of elements read from vecParams. In the case of type=="custom", the number of indices bigger than offset returned by the function indices(offset, k).

`PCMParamLocateInShortVector` *Locate a named parameter in the short vector representation of a model*

Description

Locate a named parameter in the short vector representation of a model

Usage

```
PCMParamLocateInShortVector(o, accessExpr, enclos = "?")
```

Arguments

`o`	a PCM model object.
`accessExpr`	a character string used to access the parameter, e.g. `"$Theta[,,1]"` or `"[['Theta']][,,1]"`.
`enclos`	a character string containing the symbol '?', e.g. `'diag(?)'`. The meaning of this symbol is to be replaced by the matching accessExpr (see examples). Default value : `'?'`.

Value

an integer vector of length `PCMParamCount(o)` with NAs everywhere except at the coordinates corresponding to the parameter in question.

Examples

```
model <- PCM(PCMDefaultModelTypes()["D"], k = 3, regimes = c("a", "b"))
# The parameter H is a diagonal 3x3 matrix. If this matrix is considered as
# a vector the indices of its diagonal elements are 1, 5 and 9. These indices
# are indicated as the non-NA entries in the returned vector.

PCMParamLocateInShortVector(model, "$H[,,1]")
PCMParamLocateInShortVector(model, "$H[,,'a']")
PCMParamLocateInShortVector(model, "$H[,,'b']")
PCMParamLocateInShortVector(model, "$Sigma_x[,,'b']", enclos = 'diag(?)')
PCMParamLocateInShortVector(model, "$Sigma_x[,,'b']", enclos = '?[upper.tri(?)]')
```

`PCMParamLowerLimit` *The lower limit for a given model or parameter type*

Description

This is an S3 generic function.

Usage

```
PCMParamLowerLimit(o, k, R, ...)
```

Arguments

`o`	an object such as a VectorParameter a MatrixParameter or a PCM.
`k`	integer denoting the number of traits
`R`	integer denoting the number of regimes in the model in which o belongs to.
`...`	additional arguments (optional or future use).

Value

an object of the same S3 class as o representing a lower limit for the class.

`PCMParamRandomVecParams` *Generate a random parameter vector for a model using uniform distribution between its lower and upper bounds.*

Description

Generate a random parameter vector for a model using uniform distribution between its lower and upper bounds.

Usage

```
PCMParamRandomVecParams(
  o,
  k,
  R,
  n = 1L,
  argsPCMParamLowerLimit = NULL,
  argsPCMParamUpperLimit = NULL
)
```

Arguments

`o`	a PCM model object or a parameter
`k`	integer denoting the number of traits.
`R`	integer denoting the number of regimes.
`n`	an integer specifying the number of random vectors to generate
`argsPCMParamLowerLimit, argsPCMParamUpperLimit`	named lists of arguments passed to `PCMParamLowerLimit` and `PCMParamUpperLimit`.

Value

a numeric matrix of dimension `n` x `PCMParamCount(o)`.

See Also

PCMParamLimits PCMParamGetShortVector

`PCMParamSetByName` *Set model parameters from a named list*

Description

Set model parameters from a named list

Usage

```
PCMParamSetByName(
  model,
  params,
  inplace = TRUE,
  replaceWholeParameters = FALSE,
  deepCopySubPCMs = FALSE,
  failIfNamesInParamsDontExist = TRUE,
  ...
)
```

Arguments

`model`	a PCM model object
`params`	a named list with elements among the names found in model
`inplace`	logical indicating if the parameters should be set "inplace" for the model object in the calling environment or a new model object with the parameters set as specified should be returned. Defaults to TRUE.
`replaceWholeParameters`	logical, by default set to FALSE. If TRUE, the parameters will be completely replaced, meaning that their attributes (e.g. S3 class) will be replaced as well (dangerous).
`deepCopySubPCMs`	a logical indicating whether nested PCMs should be 'deep'-copied, meaning element by element, eventually preserving the attributes as in `model`. By default this is set to FALSE, meaning that sub-PCMs found in `params` will completely overwrite the sub-PCMs with the same name in `model`.
`failIfNamesInParamsDontExist`	logical indicating if an error should be raised if `params` contains elements not existing in model. Default: TRUE.
`...`	other arguments that can be used by implementing methods.

Value

If inplace is TRUE, the function only has a side effect of setting the parameters of the model object in the calling environment; otherwise the function returns a modified copy of the model object.

`PCMParamType` *Parameter types*

Description

The parameter types are divided in the following categories:

Main type These are the "ScalarParameter", "VectorParameter" and "MatrixParameter" classes. Each model parameter must have a main type.

Scope/Omission These are the "_Global" and "_Omitted" classes. Every parameter can be global for all regimes or local for a single regime. If not specified, local scope is assumed. In some special cases a parameter (e.g. Sigmae can be omitted from a model. This is done by adding "_Omitted" to its class attribute.

Constancy (optional) These are the "_Fixed", "_Ones", "_Identity" and "_Zeros" classes.

Transformation (optional) These are the "_Transformable", "_CholeskyFactor" and "_Schur" classes.

Other properties (optional) These are the "_NonNegative", "_WithNonNegativeDiagonal", "_LowerTriangular", "_AllEqual", "_ScalarDiagonal", "_Symmetric", "_UpperTriangular", "_LowerTriangularWithDiagonal" and "_UpperTriangularWithDiagonal" classes.

Usage

```
is.Local(o)

is.Global(o)

is.ScalarParameter(o)

is.VectorParameter(o)

is.MatrixParameter(o)

is.WithCustomVecParams(o)

is.Fixed(o)

is.Zeros(o)

is.Ones(o)

is.Identity(o)

is.AllEqual(o)

is.NonNegative(o)

is.Diagonal(o)

is.ScalarDiagonal(o)

is.Symmetric(o)

is.UpperTriangular(o)

is.UpperTriangularWithDiagonal(o)

is.WithNonNegativeDiagonal(o)

is.LowerTriangular(o)

is.LowerTriangularWithDiagonal(o)

is.Omitted(o)

is.CholeskyFactor(o)

is.Schur(o)

is.Transformable(o)
is.Transformed(o)

is.SemiPositiveDefinite(o)
```

Arguments

`o`	an object, i.e. a PCM or a parameter object.

Value

logical indicating if the object passed is from the type appearing in the function-name.

Functions

- `is.Local`:
- `is.Global`:
- `is.ScalarParameter`:
- `is.VectorParameter`:
- `is.MatrixParameter`:
- `is.WithCustomVecParams`:
- `is.Fixed`:
- `is.Zeros`:
- `is.Ones`:
- `is.Identity`:
- `is.AllEqual`:
- `is.NonNegative`:
- `is.Diagonal`:
- `is.ScalarDiagonal`:
- `is.Symmetric`:
- `is.UpperTriangular`:
- `is.UpperTriangularWithDiagonal`:
- `is.WithNonNegativeDiagonal`:
- `is.LowerTriangular`:
- `is.LowerTriangularWithDiagonal`:
- `is.Omitted`:
- `is.CholeskyFactor`:
- `is.Schur`:
- `is.Transformable`:
- `is.Transformed`:
- `is.SemiPositiveDefinite`:

`PCMParamUpperLimit` *The upper limit for a given model or parameter type*

Description

This is an S3 generic function.

Usage

```
PCMParamUpperLimit(o, k, R, ...)
```

Arguments

`o`	an object such as a VectorParameter a MatrixParameter or a PCM.
`k`	integer denoting the number of traits
`R`	integer denoting the number of regimes in the model in which o belongs to.
`...`	additional arguments (optional or future use).

Value

an object of the same S3 class as o representing an upper limit for the class.

`PCMParentClasses` *Parent S3 classes for a model class*

Description

Parent S3 classes for a model class

Usage

```
PCMParentClasses(model)
```

Arguments

`model`	an S3 object.

Details

This S3 generic function is intended to be specified for user models. This function is called by the ‘PCM.character‘ method to determine the parent classes for a given model class.

Value

a vector of character string denoting the names of the parent classes

`PCMParseErrorMessage` *Extract error information from a formatted error message.*

Description

Extract error information from a formatted error message.

Usage

```
PCMParseErrorMessage(x)
```

Arguments

`x`	character string representing the error message.

Value

Currently the function returns `x` unchanged.

`PCMPExpxMeanExp` *Create a function of time that calculates* $(1 - exp(-lambda\_ij * time))/lambda\_ij$ *for every element* $lambda\_ij$ *of the input matrix* $Lambda\_ij$.

Description

Create a function of time that calculates $(1-exp(-lambda_ij*time))/lambda_ij$ for every element $lambda_ij$ of the input matrix $Lambda_ij$.

Usage

```
PCMPExpxMeanExp(
  Lambda_ij,
  threshold.Lambda_ij = getOption("PCMBase.Threshold.Lambda_ij", 1e-08)
)
```

Arguments

`Lambda_ij`	a squared numerical matrix of dimension k x k
`threshold.Lambda_ij`	a 0-threshold for abs(Lambda_i + Lambda_j), where Lambda_i and Lambda_j are eigenvalues of the parameter matrix H. This threshold-value is used as a condition to take the limit time of the expression '(1-exp(-Lambda_ij*time))/Lambda_ij' as '(Lambda_i+Lambda_j) –> 0'. You can control this value by the global option "PCMBase.Threshold.Lambda_ij". The default value (1e-8) is suitable for branch lengths bigger than 1e-6. For smaller branch lengths, you may want to increase the threshold value using, e.g. 'options(PCMBase.Threshold.Lambda_ij=1e-6)'.

Details

the function $(1 - exp(-lambda_ij * time))/lambda_ij$ corresponds to the product of the CDF of an exponential distribution with rate $Lambda_ij$ multiplied by its mean value (mean waiting time).

Value

a function of time returning a matrix with entries formed from the above function or the limit, time, if $|Lambda_{ij}| <= trehshold0$.

`PCMPLambdaP_1` *Eigen-decomposition of a matrix H*

Description

Eigen-decomposition of a matrix H

Usage

```
PCMPLambdaP_1(H)
```

Arguments

`H`	a numeric matrix

Details

The function fails with an error message if H is defective, that is, if its matrix of eigenvectors is computationally singular. The test for singularity is based on the `rcond` function.

Value

a list with elements as follows:

`lambda`	a vector of the eigenvalues of H
`P`	a squared matrix with column vectors, the eigenvectors of H corresponding to the eigenvalues in `lambda`
`P_1`	the inverse matrix of `P`

.

PCMPlotGaussianDensityGrid2D *A 2D Gaussian distribution density grid in the form of a ggplot object*

Description

A 2D Gaussian distribution density grid in the form of a ggplot object

Usage

```
PCMPlotGaussianDensityGrid2D(
  mu,
  Sigma,
  xlim,
  ylim,
  xNumPoints = 100,
  yNumPoints = 100,
  ...
)
```

Arguments

`mu`	numerical mean vector of length 2
`Sigma`	numerical 2 x 2 covariance matrix
`xlim, ylim`	numerical vectors of length 2
`xNumPoints, yNumPoints`	integers denoting how many points should the grid contain for each axis.
`...`	additional arguments passed to ggplot

Value

a ggplot object

PCMPlotGaussianSample2D *A 2D sample from Gaussian distribution*

Description

A 2D sample from Gaussian distribution

Usage

```
PCMPlotGaussianSample2D(mu, Sigma, numPoints = 1000, ...)
```

Arguments

`mu`	numerical mean vector of length 2
`Sigma`	numerical 2 x 2 covariance matrix
`numPoints`	an integer denoting how many points should be randomly sampled (see details).
`...`	additional arguments passed to ggplot.

Details

This function generates a random sample of numPoints 2d points using the function rmvnorm from the mvtnorm R-package. Then it produces a ggplot on the generated points.

Value

a ggplot object

`PCMPlotMath` *Beautiful model description based on plotmath*

Description

This is an S3 generic that produces a plotmath expression for its argument.

Usage

```
PCMPlotMath(o, roundDigits = 2, transformSigma_x = FALSE)
```

Arguments

`o`	a PCM or a parameter object.
`roundDigits`	an integer, default: 2.
`transformSigma_x`	a logical indicating if Cholesky transformation should be applied to Cholesky-factor parameters prior to generating the plotmath expression.

Value

a character string.

PCMPlotTraitData2D *Scatter plot of 2-dimensional data*

Description

Scatter plot of 2-dimensional data

Usage

```
PCMPlotTraitData2D(
  X,
  tree,
  sizePoints = 2,
  alphaPoints = 1,
  labeledTips = NULL,
  sizeLabels = 8,
  nudgeLabels = c(0, 0),
  palette = PCMColorPalette(PCMNumRegimes(tree), PCMRegimes(tree)),
  scaleSizeWithTime = !is.ultrametric(tree),
  numTimeFacets = if (is.ultrametric(tree) || scaleSizeWithTime) 1L else 3L,
  nrowTimeFacets = 1L,
  ncolTimeFacets = numTimeFacets
)
```

Arguments

`X`	a k x N matrix
`tree`	a phylo object
`sizePoints, alphaPoints`	numeric parameters passed as arguments size and alpha to `geom_point`. Default: sizePoints = 2, alphaPoints = 1.
`labeledTips`	a vector of tip-numbers to label (NULL by default)
`sizeLabels`	passed to `geom_text` to specify the size of tip-labels for the trait-points.
`nudgeLabels`	a numeric vector of two elements (default: c(0,0)), passed as arguments nudge_x and nudge_y of `geom_text`.
`palette`	a named vector of colors
`scaleSizeWithTime`	logical indicating if the size and the transparency of the points should reflect the distance from the present (points that are farther away in time with respect to the present moment, i.e. closer to the root of the tree, are displayed smaller and more transparent.). By default this is set to `!is.ultrametric(tree)`.
`numTimeFacets`	a number or a numeric vector controlling the creation of different facets corresponding to different time intervals when the tree is non-ultrametric. If a single number, it will be interpreted as an integer specifying the number of facets, each facets corresponding to an equal interval of time. If a numeric vector, it will be

	used to specify the cut-points for each interval. Default: `if(is.ultrametric(tree) || scaleSizeWithTime) 1L else 3`.
`nrowTimeFacets, ncolTimeFacets`	integers specifying how the time facets should be layed out. Default: `nrowTimeFacets = 1L, ncolTimeFacets = numTimeFacets`.

Value

a ggplot object

`PCMPresentCoordinates` *Determine which traits are present (active) on each node of the tree*

Description

For every node (root, internal or tip) in tree, build a logical vector of length k with TRUE values for every present coordinate. Non-present coordinates arize from NA-values in the trait data. These can occur in two cases:

Missing measurements for some traits at some tips: the present coordinates are FALSE for the corresponding tip and trait, but are full for all traits at all internal and root nodes.

non-existent traits for some species: the FALSE present coordinates propagate towards the parent nodes - an internal or root node will have a present coordinate set to FALSE for a given trait, if all of its descendants have this coordinate set to FALSE.

These two cases have different effect on the likelihood calculation: missing measurements (NA) are integrated out at the parent nodes; while non-existent traits (NaN) are treated as reduced dimensionality of the vector at the parent node.

Usage

```
PCMPresentCoordinates(X, tree, metaI)
```

Arguments

`X`	numeric k x N matrix of observed values, with possible NA entries. The columns in X are in the order of tree$tip.label
`tree`	a phylo object
`metaI`	The result of calling PCMInfo.

Value

a k x M logical matrix. The function fails in case when all traits are NAs for some of the tips. In that case an error message is issued "PCMPresentCoordinates:: Some tips have 0 present coordinates. Consider removing these tips.".

See Also

`PCMLik`

PCMRegimes — *Get the regimes (aka colors) of a PCM or of a PCMTree object*

Description

Get the regimes (aka colors) of a PCM or of a PCMTree object

Usage

```
PCMRegimes(obj)
```

Arguments

`obj`	a PCM or a PCMTree object

Value

a character or an integer vector giving the regime names in the obj

PCMSetAttribute — *Set an attribute of a named member in a PCM or other named list object*

Description

Set an attribute of a named member in a PCM or other named list object

Usage

```
PCMSetAttribute(
  name,
  value,
  object,
  member = "",
  spec = TRUE,
  inplace = TRUE,
  ...
)
```

Arguments

`name`	a character string denoting the attribute name.
`value`	the value for the attribute.
`object`	a PCM or a list object.
`member`	a member expression. Member expressions are character strings denoting named elements in a list object (see examples). Default: "".
`spec`	a logical (TRUE by default) indicating if the attribute should also be set in the corresponding member of the spec attribute (this is for PCM objects only).
`inplace`	logical (TRUE by default) indicating if the attribute should be set to the object in the current environment, or a modified object should be returned.
`...`	additional arguments passed to `MatchListMembers`.

Details

Calling this function can affect the attributes of multiple members matched by the `member` argument.

Value

if inplace is TRUE (default) nothing is returned. Otherwise, a modified version of object is returned.

Examples

```
model <- PCMBaseTestObjects$model_MixedGaussian_ab
PCMSetAttribute("class", c("MatrixParameter", "_Fixed"), model, "H")
```

PCMSim *Simulation of a phylogenetic comparative model on a tree*

Description

Generate trait data on a tree according to a multivariate stochastic model with one or several regimes

Usage

```
PCMSim(
  tree,
  model,
  X0,
  SE = matrix(0, PCMNumTraits(model), PCMTreeNumTips(tree)),
 metaI = PCMInfo(X = NULL, tree = tree, model = model, SE = SE, verbose = verbose),
  verbose = FALSE
)
```

Arguments

`tree`	a phylo object specifying a rooted tree.
`model`	an S3 object specifying the model (see Details).
`X0`	a numeric vector of length k (the number of traits) specifying the trait values at the root of the tree.
`SE`	a k x N matrix specifying the standard error for each measurement in X. Alternatively, a k x k x N cube specifying an upper triangular k x k factor of the variance covariance matrix for the measurement error for each node i=1, ..., N. Default: `matrix(0.0, PCMNumTraits(model), PCMTreeNumTips(tree))`.
`metaI`	a named list containing meta-information about the data and the model.
`verbose`	a logical indicating if informative messages should be written during execution.

Details

Internally, this function uses the `PCMCond` implementation for the given model class.

Value

numeric M x k matrix of values at all nodes of the tree, i.e. root, internal and tip, where M is the number of nodes: `M=dim(tree$edge)[1]+1`, with indices from 1 to N=length(tree$tip.label) corresponding to tips, N+1 corresponding to the root and bigger than N+1 corresponding to internal nodes. The function will fail in case that the length of the argument vector X0 differs from the number of traits specified in `metaI$k`. Error message: "PCMSim:: X0 must be of length ...".

See Also

`PCMLik` `PCMInfo` `PCMCond`

Examples

```
N <- 10
L <- 100.0
tr <- ape::stree(N)
tr$edge.length <- rep(L, N)
for(epoch in seq(1, L, by = 1.0)) {
  tr <- PCMTreeInsertSingletonsAtEpoch(tr, epoch)
}

model <- PCMBaseTestObjects$model_MixedGaussian_ab

PCMTreeSetPartRegimes(tr, c(`11` = 'a'), setPartition = TRUE)

set.seed(1, kind = "Mersenne-Twister", normal.kind = "Inversion")
X <- PCMSim(tr, model, X0 = rep(0, 3))
```

`PCMSpecify` *Parameter specification of PCM model*

Description

The parameter specification of a PCM model represents a named list with an entry for each parameter of the model. Each entry in the list is a structure defining the S3 class of the parameter and its verbal description. This is an S3 generic. See ‘PCMSpecify.OU‘ for an example method.

Usage

```
PCMSpecify(model, ...)
```

Arguments

`model`	a PCM model object.
`...`	additional arguments used by implementing methods.

Value

a list specifying the parameters of a PCM.

`PCMTable` *A data.table representation of a PCM object*

Description

A data.table representation of a PCM object

Usage

```
PCMTable(
  model,
  skipGlobalRegime = FALSE,
  addTransformed = TRUE,
  removeUntransformed = TRUE
)
```

Arguments

`model`	a PCM object.
`skipGlobalRegime`	logical indicating whether a raw in the returned table for the global-scope parameters should be omitted (this is mostly for internal use). Default (FALSE).

`addTransformed`	logical. If TRUE (the default), columns for the transformed version of the transformable parameters will be added.
`removeUntransformed`	logical If TRUE (default), columns for the untransformed version of the transformable parameters will be omitted.

Details

This is an S3 generic.

Value

an object of S3 class PCMTable

`PCMTableParameterizations`

Cartesian product of possible parameterizations for the different parameters of a model

---

Description

This function generates a data.table in which each column corresponds to one parameter of model and each row corresponds to one combination of parameterizations for the model parameters, such that the whole table corresponds to the Cartesian product of the lists found in ‘listParameterizations‘. Usually, subsets of this table should be passed to ‘PCMGenerateParameterizations‘

Usage

```
PCMTableParameterizations(
  model,
  listParameterizations = PCMListParameterizations(model, ...),
  ...
)
```

Arguments

`model`	a PCM object.
`listParameterizations`	a list returned by a method for ‘PCMListParameterizations‘. Default: ‘PCMListParameterizations(model, ...)‘.
`...`	additional arguments passed to ‘PCMListParameterizations(model, ...)‘.

Value

a data.table object.

PCMTrajectory *Generate a trajectory for the mean in one regime of a PCM*

Description

Generate a trajectory for the mean in one regime of a PCM

Usage

```
PCMTrajectory(
  model,
  regime = PCMRegimes(model)[1],
  X0 = rep(0, PCMNumTraits(model)),
  W0 = matrix(0, nrow = PCMNumTraits(model), ncol = PCMNumTraits(model)),
  tX = seq(0, 100, by = 1),
  tVar = tX[seq(0, length(tX), length.out = 4)],
  dims = seq_len(PCMNumTraits(model)),
  sizeSamp = 100,
  doPlot2D = FALSE,
  plot = NULL
)
```

Arguments

`model`	a PCM object.
`regime`	a regime in ‘model‘. Default is PCMRegimes(model)[1].
`X0`	a numeric vector specifying an initial point in the trait space. Default is rep(0, PCMNumTraits(model))
`W0`	a numeric k x k symmetric positive definite matrix or 0 matrix, specifying the initial variance covariance matrix at t0. By default, this is a k x k 0 matrix.
`tX, tVar`	numeric vectors of positive points in time sorted in increasing order. tX specifies the points in time at which to calculate the mean (conditional on X0). tVar specifies a subset of the points in tX at which to generate random samples from the k-variate Gaussian distribution with mean equal to the mean value at the corresponding time conditional on X0 and variance equal to the variance at this time, conditional on W0. Default settings are ‘tX = seq(0, 100, by = 1)‘ and ‘tVar = tX[seq(0, length(tX), length.out = 4)]‘.
`dims`	an integer vector specifying the traits for which samples at tVar should be generated (see tX,tVar above). Default: seq_len(PCMNumTraits(model)).
`sizeSamp`	an integer specifying the number points in the random samples (see tX and tVar above). Default 100.
`doPlot2D`	Should a ggplot object be produced and returned. This is possible only for two of the traits specified in dims. Default: FALSE.
`plot`	a ggplot object. This can be specified when doPlot2D is TRUE and allows to add the plot of this trajectory as a layer in an existing ggplot. Default: NULL

Value

if doPlot2D is TRUE, returns a ggplot. Otherwise a named list of two elements:

dt a data.table with columns 'regime', 't', 'X', 'V' and 'samp'. For each row corresponding to time in tVar, the column samp represents a list of sizeSamp k-vectors.

dtPlot a data.table with the same data as in dt, but with converted columns X and samp into 2 x k columns denoted xi, i=1,...,k and xsi (i=1...k) This is suitable for plotting with ggplot.

Examples

```
set.seed(1, kind = "Mersenne-Twister", normal.kind = "Inversion")

# a Brownian motion model with one regime
modelOU <- PCM(model = PCMDefaultModelTypes()['F'], k = 2)

# assign the model parameters at random: this will use uniform distribution
# with boundaries specified by PCMParamLowerLimit and PCMParamUpperLimit
# We do this in two steps:
# 1. First we generate a random vector. Note the length of the vector equals
# PCMParamCount(modelBM).

randomParams <- PCMParamRandomVecParams(
  modelOU, PCMNumTraits(modelOU), PCMNumRegimes(modelOU))
# 2. Then we load this random vector into the model.
PCMParamLoadOrStore(
  modelOU,
  randomParams,
  0, PCMNumTraits(modelBM), PCMNumRegimes(modelBM), load = TRUE)

# let's plot the trajectory of the model starting from X0 = c(0,0)
PCMTrajectory(
  model = modelOU,
  X0 = c(0, 0),
  doPlot2D = TRUE)


# A faceted grid of plots for the two regimes in a mixed model:
pla <- PCMTrajectory(
  model = PCMBaseTestObjects$model_MixedGaussian_ab, regime = "a",
  X0 = c(0, 0, 0),
  doPlot2D = TRUE) +
  ggplot2::scale_y_continuous(limits = c(0, 10)) +
  ggplot2::facet_grid(.~regime)

plb <- PCMTrajectory(
  model = PCMBaseTestObjects$model_MixedGaussian_ab, regime = "b",
  X0 = c(0, 0, 0),
  doPlot2D = TRUE) +
  ggplot2::scale_y_continuous(limits = c(0, 10)) +
  ggplot2::facet_grid(.~regime) +
  ggplot2::theme(
    axis.title.y = ggplot2::element_blank(),
    axis.text.y = ggplot2::element_blank(),
    axis.ticks.y = ggplot2::element_blank())

plot(pla)
plot(plb)
```

`PCMTree` *Create a PCMTree object from a phylo object*

Description

PCMTree is class that inherits from the class 'phylo' in the R-package 'ape'. Thus, all the functions working on a phylo object would work in the same way if they receive as argument an object of class 'PCMTree'. A PCMTree object has the following members in addition to the regular members ('tip.label', 'node.label', 'edge', 'edge.length') found in a regular phylo object:

edge.part a character vector having as many elements as there are branches in the tree (corresponding to the rows in 'tree$edge'). Each element denotes the name of the part to which the corresponding branch belongs. A part in the tree represents a connected subset of its nodes and the branches leading to these nodes. A partition of the tree represents the splitting of the tree into a number of parts. Visually, a partition can be represented as a coloring of the tree, in which no color is assigned to more than one part. In other words, if two branches in the tree are connected by the same color, they either share a node, or all the branches on the path in the tree connecting these two branches have the same color. Formally, we define a partition of the tree as any set of nodes in the tree that includes the root. Each node in this set defines a part as the set of its descendant nodes that can be reached without traversing another partition node. We name each part by the label of its most ancestral node, that is, the node in it, which is closest to the root fo the tree. The value of edge.part for an edge in the tree is the name of the part that contains the node to which the edge is pointing.

part.regime a named vector of size the number of parts in the tree. The names correspond to part-names whereas the values denote the ids or character names of regimes in a PCM object.

The constructor PCMTree() returns an object of call

Usage

```
PCMTree(tree)
```

Arguments

`tree`	a phylo object. If this is already a PCMTree object, a copy of this object will be returned.

Value

an object of class PCMTree. This is a copy of the passed phylo object which is guaranteed to have node.label, edge.part and a part.regime entries set.

Examples

```
tree <- ape::rtree(8)

# the following four are NULLs
tree$node.label
tree$edge.part
tree$part.regime
tree$edge.regime

# In previous version regimes were assigned directly to the edges via
# tree$edge.regime. This is supported but not recommended anymore:

tree$edge.regime <- sample(
  letters[1:3], size = PCMTreeNumNodes(tree) - 1, replace = TRUE)

tree.a <- PCMTree(tree)
PCMTreeGetLabels(tree.a)
tree.a$node.label
tree.a$edge.part
tree.a$part.regime

# this is set to NULL - starting from PCMBase 1.2.9 all of the information
# for the regimes is stored in tree$edge.part and tree$part.regime.
tree.a$edge.regime

PCMTreeGetPartition(tree.a)
PCMTreeGetPartNames(tree.a)
PCMTreeGetPartRegimes(tree.a)

# let's see how the tree looks like
if(requireNamespace("ggtree"))
PCMTreePlot(tree.a) + ggtree::geom_nodelab() + ggtree::geom_tiplab()

# This is the recommended way to set a partition on the tree
PCMTreeSetPartition(tree.a, c(10, 12))

PCMTreeGetPartition(tree.a)
PCMTreeGetPartNames(tree.a)
PCMTreeGetPartRegimes(tree.a)



if(requireNamespace("ggtree"))
PCMTreePlot(tree.a) + ggtree::geom_nodelab() + ggtree::geom_tiplab()

PCMTreeGetPartsForNodes(tree.a, c(11, 15, 12))
PCMTreeGetPartsForNodes(tree.a, c("11", "15", "12"))

PCMTreeSetPartRegimes(tree.a, c(`9` = 'a', `10` = 'b', `12` = 'c'))

PCMTreeGetPartition(tree.a)
PCMTreeGetPartNames(tree.a)
```

```
PCMTreeGetPartRegimes(tree.a)

if(requireNamespace("ggtree"))
PCMTreePlot(tree.a) + ggtree::geom_nodelab() + ggtree::geom_tiplab()
```

PCMTreeBackbonePartition

Prune the tree leaving one tip for each or some of its parts

Description

Prune the tree leaving one tip for each or some of its parts

Usage

```
PCMTreeBackbonePartition(tree, partsToKeep = PCMTreeGetPartNames(tree))
```

Arguments

`tree`	a PCMTree or a phylo object.
`partsToKeep`	a character vector denoting part names in the tree to be kept. Defaults to 'PCMTreeGetPartNames(tree)'.

Value

a PCMTree object representing a pruned version of tree.

See Also

PCMTreeSetPartition

PCMTree

Examples

```
set.seed(1, kind = "Mersenne-Twister", normal.kind = "Inversion")
tree <- PCMTree(ape::rtree(25))

if(requireNamespace("ggtree"))
PCMTreePlot(tree) + ggtree::geom_nodelab(angle = 45) +
  ggtree::geom_tiplab(angle = 45)

backb <-  PCMTreeBackbonePartition(tree)

if(requireNamespace("ggtree"))
PCMTreePlot(backb) + ggtree::geom_nodelab(angle = 45) +
  ggtree::geom_tiplab(angle = 45)

tree2 <- PCMTreeSetPartRegimes(
  tree, c(`26` = "a", `28` = "b"), setPartition = TRUE,
  inplace = FALSE)

if(requireNamespace("ggtree"))
PCMTreePlot(tree2) + ggtree::geom_nodelab(angle = 45) +
  ggtree::geom_tiplab(angle = 45)

backb <-  PCMTreeBackbonePartition(tree2)

if(requireNamespace("ggtree"))
PCMTreePlot(backb) + ggtree::geom_nodelab(angle = 45) +
  ggtree::geom_tiplab(angle = 45)

tree3 <- PCMTreeSetPartRegimes(
  tree, c(`26` = "a", `28` = "b", `41` = "c"), setPartition = TRUE,
  inplace = FALSE)

if(requireNamespace("ggtree"))
PCMTreePlot(tree3) + ggtree::geom_nodelab(angle = 45) +
  ggtree::geom_tiplab(angle = 45)

backb <-  PCMTreeBackbonePartition(tree3)

if(requireNamespace("ggtree"))
PCMTreePlot(backb) + ggtree::geom_nodelab(angle = 45) +
  ggtree::geom_tiplab(angle = 45)

backb41 <-  PCMTreeBackbonePartition(tree3, partsToKeep = "41")

if(requireNamespace("ggtree"))
PCMTreePlot(backb41) + ggtree::geom_nodelab(angle = 45) +
  ggtree::geom_tiplab(angle = 45)

backbMoreNodes <- PCMTreeInsertSingletonsAtEpoch(
   backb, epoch = 3.7, minLength = 0.001)
PCMTreeGetPartRegimes(backbMoreNodes)

if(requireNamespace("ggtree"))
PCMTreePlot(backbMoreNodes) + ggtree::geom_nodelab(angle=45) +
  ggtree::geom_tiplab(angle=45)

backbMoreNodes <- PCMTreeInsertSingletonsAtEpoch(
   backbMoreNodes, epoch = 0.2, minLength = 0.001)
PCMTreeGetPartRegimes(backbMoreNodes)

if(requireNamespace("ggtree"))
PCMTreePlot(backbMoreNodes) + ggtree::geom_nodelab(angle=45) +
  ggtree::geom_tiplab(angle=45)

backbMoreNodes <- PCMTreeInsertSingletonsAtEpoch(
   backbMoreNodes, epoch = 1.2, minLength = 0.001)
PCMTreeGetPartRegimes(backbMoreNodes)
```

```
if(requireNamespace("ggtree"))
PCMTreePlot(backbMoreNodes) + ggtree::geom_nodelab(angle=45) +
  ggtree::geom_tiplab(angle=45)
```

PCMTreeDropClade *Drop a clade from a phylogenetic tree*

Description

Drop a clade from a phylogenetic tree

Usage

```
PCMTreeDropClade(
  tree,
  cladeRootNode,
  tableAncestors = NULL,
  X = NULL,
  returnList = !is.null(X),
  errorOnMissing = FALSE
)
```

Arguments

`tree`	a phylo object
`cladeRootNode`	a character string denoting the label or an integer denoting a node in the tree
`tableAncestors`	an integer matrix returned by a previous call to PCMTreeTableAncestors(tree) or NULL.
`X`	an optional k x N matrix with trait value vectors for each tip in tree.
`returnList`	logical indicating if a list of the phylo object associated with the tree after dropping the clade and the corresponding entries in X should be returned. Defaults to `!is.null(X)`
`errorOnMissing`	logical indicating if an error should be raised if cladeRootNode is not among the nodes in tree. Default FALSE, meaning that if cladeRootNode is not a node in tree the tree (and X if returnList is TRUE) is/are returned unchanged.

Value

If returnList is FALSE, a phylo object associated with the remaining tree after dropping the clade, otherise, a list with two named members :

tree the phylo object associated with the remaining tree after dropping the clade

X the submatrix of X with columns corresponding to the tips in the remaining tree

See Also

PCMTreeSpliAtNode PCMTreeExtractClade

Examples

```
set.seed(1, kind = "Mersenne-Twister", normal.kind = "Inversion")
tree <- PCMTree(ape::rtree(25))
PCMTreeSetPartRegimes(
  tree, c(`26`="a", `28`="b", `45`="c"), setPartition = TRUE)

if(requireNamespace("ggtree"))
PCMTreePlot(tree, palette=c(a = "red", b = "green", c = "blue")) +
  ggtree::geom_nodelab(angle = 45) + ggtree::geom_tiplab(angle = 45)

redGreenTree <- PCMTreeDropClade(tree, 45)
PCMTreeGetPartRegimes(redGreenTree)

if(requireNamespace("ggtree"))
PCMTreePlot(redGreenTree, palette=c(a = "red", b = "green", c = "blue")) +
  ggtree::geom_nodelab(angle = 45) + ggtree::geom_tiplab(angle = 45)

# we need to use the label here, because the node 29 in tree is not the same
# id in redGreenTree:
redGreenTree2 <- PCMTreeDropClade(redGreenTree, "29")

if(requireNamespace("ggtree"))
PCMTreePlot(redGreenTree2, palette=c(a = "red", b = "green", c = "blue")) +
  ggtree::geom_nodelab(angle = 45) + ggtree::geom_tiplab(angle = 45)
```

PCMTreeDtNodes — *A data.table with time, part and regime information for the nodes in a tree*

Description

A data.table with time, part and regime information for the nodes in a tree

Usage

```
PCMTreeDtNodes(tree)
```

Arguments

`tree`	a phylo object with node-labels and parts

Value

a data.table with a row for each node in tree and columns as follows:

startNode the starting node of each edge or NA_integer_ for the root

endNode the end node of each edge or the root id for the root

startNodeLab the character label for the startNode

endNodeLab the character label for endNode

startTime the time (distance from the root node) for the startNode or NA_real_ for the root node

endTime the time (distance from the root node) for the endNode or NA_real_ for the root node

part the part to which the edge belongs, i.e. the part of the endNode

regime the regime to which the edge belongs, i.e. the regime of the part of the endNode

Examples

```
PCMTreeDtNodes(PCMBaseTestObjects$tree.ab)
```

`PCMTreeEdgeTimes` *A matrix with the begin and end time from the root for each edge in tree*

Description

A matrix with the begin and end time from the root for each edge in tree

Usage

```
PCMTreeEdgeTimes(tree)
```

Arguments

`tree`	a phylo

PCMTreeEvalNestedEDxOnTree

Perfrorm nested extractions or drops of clades from a tree

Description

Perfrorm nested extractions or drops of clades from a tree

Usage

```
PCMTreeEvalNestedEDxOnTree(expr, tree)
```

Arguments

`expr`	a character string representing an R expression of nested calls of functions `E(x,node)` denoting extracting the clade rooted at node from the tree x, or `D(x,node)`, denoting dropping the clade rooted at node from the tree x. These calls can be nested, i.e. x can be either the symbol x (corresponding to the original tree passed as argument) or a nested call to d or e.
`tree`	a phylo object with named tips and internal nodes

Value

the resulting phylo object from evaluating expr on tree.

Examples

```
set.seed(1, kind = "Mersenne-Twister", normal.kind = "Inversion")
tree <- PCMTree(ape::rtree(25))
PCMTreeSetPartRegimes(
  tree, c(`26`="a", `28`="b", `45`="c", `47`="d"), setPartition = TRUE)

if(requireNamespace("ggtree"))
PCMTreePlot(
  tree, palette=c(a = "red", b = "green", c = "blue", d = "magenta")) +
  ggtree::geom_nodelab(angle = 45) + ggtree::geom_tiplab(angle = 45)

bluePart <- PCMTreeEvalNestedEDxOnTree("D(E(tree,45),47)", tree)
PCMTreeGetPartRegimes(bluePart)

if(requireNamespace("ggtree"))
PCMTreePlot(
  bluePart, palette=c(a = "red", b = "green", c = "blue", d = "magenta")) +
  ggtree::geom_nodelab(angle = 45) + ggtree::geom_tiplab(angle = 45)

# Swapping the D and E calls has the same result:
bluePart2 <- PCMTreeEvalNestedEDxOnTree("E(D(tree,47),45)", tree)
PCMTreeGetPartRegimes(bluePart2)
```

```
if(requireNamespace("ggtree"))
PCMTreePlot(
  bluePart2, palette=c(a = "red", b = "green", c = "blue", d = "magenta")) +
  ggtree::geom_nodelab(angle = 45) + ggtree::geom_tiplab(angle = 45)

greenPart <- PCMTreeEvalNestedEDxOnTree("E(tree,28)", tree)

bgParts <- bluePart+greenPart


if(requireNamespace("ggtree")) {
PCMTreePlot(
  greenPart, palette=c(a = "red", b = "green", c = "blue", d = "magenta")) +
  ggtree::geom_nodelab(angle = 45) + ggtree::geom_tiplab(angle = 45)
PCMTreePlot(
  bluePart + greenPart, palette=c(a = "red", b = "green", c = "blue", d = "magenta")) +
  ggtree::geom_nodelab(angle = 45) + ggtree::geom_tiplab(angle = 45)
PCMTreePlot(
  greenPart + bluePart, palette=c(a = "red", b = "green", c = "blue", d = "magenta")) +
  ggtree::geom_nodelab(angle = 45) + ggtree::geom_tiplab(angle = 45)
PCMTreePlot(
  bgParts, palette=c(a = "red", b = "green", c = "blue", d = "magenta")) +
  ggtree::geom_nodelab(angle = 45) + ggtree::geom_tiplab(angle = 45)
}
```

PCMTreeExtractClade *Extract a clade from phylogenetic tree*

Description

Extract a clade from phylogenetic tree

Usage

```
PCMTreeExtractClade(
  tree,
  cladeRootNode,
  tableAncestors = NULL,
  X = NULL,
  returnList = !is.null(X)
)
```

Arguments

`tree`	a PCMTree object.
`cladeRootNode`	a character string denoting the label or an integer denoting a node in the tree.
`tableAncestors`	an integer matrix returned by a previous call to PCMTreeTableAncestors(tree) or NULL.

`X`	an optional k x N matrix with trait value vectors for each tip in tree.
`returnList`	logical indicating if only the phylo object associated with the clade should be returned. Defaults to `!is.null(X)`

Value

If returnList is FALSE, a phylo object associated with the clade, otherwise, a list with two named members :

tree the phylo object associated with the clade

X the submatrix of X with columns corresponding to the tips in the clade

See Also

PCMTreeSpliAtNode PCMTreeDropClade

Examples

```
set.seed(1, kind = "Mersenne-Twister", normal.kind = "Inversion")
tree <- PCMTree(ape::rtree(25))
PCMTreeSetPartRegimes(
  tree, c(`26`="a", `28`="b", `45`="c"), setPartition = TRUE)

if(requireNamespace("ggtree"))
PCMTreePlot(tree, palette=c(a = "red", b = "green", c = "blue")) +
  ggtree::geom_nodelab(angle = 45) + ggtree::geom_tiplab(angle = 45)

blueTree <- PCMTreeExtractClade(tree, 45)
PCMTreeGetPartRegimes(blueTree)

if(requireNamespace("ggtree"))
PCMTreePlot(blueTree, palette=c(a = "red", b = "green", c = "blue")) +
  ggtree::geom_nodelab(angle = 45) + ggtree::geom_tiplab(angle = 45)

# we need to use the label here, because the node 29 in tree is not the same
# id in redGreenTree:
blueTree2 <- PCMTreeDropClade(blueTree, "48")

if(requireNamespace("ggtree"))
PCMTreePlot(blueTree2, palette=c(a = "red", b = "green", c = "blue")) +
  ggtree::geom_nodelab(angle = 45) + ggtree::geom_tiplab(angle = 45)
```

`PCMTreeGetBranchLength` *The length of the branch leading to a node*

Description

The length of the branch leading to a node

Usage

```
PCMTreeGetBranchLength(tree, daughterId)
```

Arguments

`tree`	a phylo object.
`daughterId`	an integer denoting the id of a daughter node

Value

a double denoting the length of the branch leading to daughterId

---

`PCMTreeGetDaughters` *A vector of the daughter nodes for a given parent node id in a tree*

Description

A vector of the daughter nodes for a given parent node id in a tree

Usage

```
PCMTreeGetDaughters(tree, parentId)
```

Arguments

`tree`	a phylo object.
`parentId`	an integer denoting the id of the parent node

Value

an integer vector of the direct descendants of parentId

`PCMTreeGetLabels` *Node labels of a tree*

Description

Get the character labels of the tips, root and internal nodes in the tree (see Functions below).

Usage

```
PCMTreeGetLabels(tree)

PCMTreeGetRootLabel(tree)

PCMTreeGetNodeLabels(tree)

PCMTreeGetTipLabels(tree)
```

Arguments

`tree`	a phylo object

Value

a character vector

Functions

- `PCMTreeGetLabels`: Get all labels in the order (tips,root,internal).
- `PCMTreeGetRootLabel`: Get the root label
- `PCMTreeGetNodeLabels`: Get the internal node labels
- `PCMTreeGetTipLabels`: Get the tip labels

`PCMTreeGetParent` *The parent node id of a daughter node in a tree*

Description

The parent node id of a daughter node in a tree

Usage

```
PCMTreeGetParent(tree, daughterId)
```

Arguments

`tree`	a phylo object.
`daughterId`	an integer denoting the id of the daughter node

Value

an integer denoting the parent of daughterId

PCMTreeGetPartition *Get the starting branch' nodes for each part on a tree*

Description

Get the starting branch' nodes for each part on a tree

Usage

```
PCMTreeGetPartition(tree)
```

Arguments

`tree`	a phylo object with an edge.part member denoting parts. The function assumes that each part covers a linked set of branches on the tree.

Details

We call a starting branch the first branch from the root to the tips of a given part. A starting node is the node at which a starting branch ends.

Value

a named integer vector with elements equal to the starting nodes for each part in tree and names equal to the labels of these nodes.

See Also

`PCMTreeSetPartition`

Examples

```
set.seed(1, kind = "Mersenne-Twister", normal.kind = "Inversion")
PCMTreeGetPartition(PCMTree(ape::rtree(20)))
```

PCMTreeGetPartNames *Unique parts on a tree in the order of occurrence from the root to the tips (preorder)*

Description

Unique parts on a tree in the order of occurrence from the root to the tips (preorder)

Usage

```
PCMTreeGetPartNames(tree)
```

Arguments

`tree`	a phylo object with an additional member edge.part which should be a character or an integer vector of length equal to the number of branches.

Value

a character vector.

`PCMTreeGetPartRegimes` *Regime mapping for the parts in a tree*

Description

Regime mapping for the parts in a tree

Usage

```
PCMTreeGetPartRegimes(tree)
```

Arguments

`tree`	a PCMTree or a phylo object.

Value

a named vector with names corresponding to the part names in tree and values corresponding to regime names or ids.

`PCMTreeGetPartsForNodes` *Get the parts of the branches leading to a set of nodes or tips*

Description

Get the parts of the branches leading to a set of nodes or tips

Usage

```
PCMTreeGetPartsForNodes(tree, nodes = seq_len(PCMTreeNumNodes(tree)))
```

Arguments

`tree`	a phylo object with an edge.part member denoting parts.
`nodes`	an integer vector denoting the nodes. Default is seq_len(PCMTreeNumNodes(tree).

Value

a character vector denoting the parts of the branches leading to the nodes, according to tree$edge.part.

PCMTreeGetRegimesForEdges

Model regimes (i.e. colors) associated with the branches in a tree

Description

Model regimes (i.e. colors) associated with the branches in a tree

Usage

```
PCMTreeGetRegimesForEdges(tree)
```

Arguments

`tree`	a PCMTree or a phylo object.

Value

a vector with entries corresponding to the rows in tree$edge denoting the regime associated with each branch in the tree. The type of the vector element is defined by the type of tree$part.regime.

PCMTreeGetRegimesForNodes

Get the regimes of the branches leading to a set of nodes or tips

Description

Get the regimes of the branches leading to a set of nodes or tips

Usage

```
PCMTreeGetRegimesForNodes(tree, nodes = seq_len(PCMTreeNumNodes(tree)))
```

Arguments

`tree`	a phylo object with an edge.part member denoting parts.
`nodes`	an integer vector denoting the nodes. Default is seq_len(PCMTreeNumNodes(tree).

Value

a character vector denoting the parts of the branches leading to the nodes, according to tree$edge.part.

PCMTreeGetTipsInPart *Get the tips belonging to a part in a tree*

Description

Get the tips belonging to a part in a tree

Usage

```
PCMTreeGetTipsInPart(tree, part)
```

Arguments

tree	a phylo object with an edge.regime member or a PCMTree object
part	a character or integer denoting a part name in the tree.

Value

an integer vector with the ids of the tips belonging to part

See Also

PCMTreeGetTipsInRegime, PCMTreeGetPartNames, PCMRegimes, PCMTreeGetPartRegimes, PCMTreeSetPartRegimes

Examples

```
set.seed(1, kind = "Mersenne-Twister", normal.kind = "Inversion")
tree <- ape::rtree(10)
regimes <- sample(letters[1:3], nrow(tree$edge), replace = TRUE)
PCMTreeSetRegimesForEdges(tree, regimes)

if(requireNamespace("ggtree"))
PCMTreePlot(tree) + ggtree::geom_nodelab() + ggtree::geom_tiplab()

part <- PCMTreeGetPartNames(tree)[1]
PCMTreeGetTipsInPart(tree, part)
print(part)
```

`PCMTreeGetTipsInRegime` *Get the tips belonging to a regime in a tree*

Description

Get the tips belonging to a regime in a tree

Usage

```
PCMTreeGetTipsInRegime(tree, regime)
```

Arguments

`tree`	a phylo object with an edge.regime member or a PCMTree object
`regime`	a character or integer denoting a regime in the tree.

Value

an integer vector with the ids of the tips belonging to regime.

See Also

PCMTreeGetTipsInPart, PCMTreeGetPartNames, PCMRegimes, PCMTreeGetPartRegimes, PCMTreeSetPartRegimes, PCMTreeGetPartition

Examples

```
set.seed(1, kind = "Mersenne-Twister", normal.kind = "Inversion")
tree <- ape::rtree(10)
regimes <- sample(letters[1:3], nrow(tree$edge), replace = TRUE)
PCMTreeSetRegimesForEdges(tree, regimes)

if(requireNamespace("ggtree"))
PCMTreePlot(tree) + ggtree::geom_nodelab() + ggtree::geom_tiplab()

regime <- PCMRegimes(tree)[1]
PCMTreeGetTipsInRegime(tree, regime)
print(regime)
```

`PCMTreeInsertSingletons` *Insert tips or singleton nodes on chosen edges*

Description

Insert tips or singleton nodes on chosen edges

Usage

```
PCMTreeInsertSingletons(tree, nodes, positions)

PCMTreeInsertSingletonsAtEpoch(tree, epoch, minLength = 0.1)

PCMTreeInsertTipsOrSingletons(
  tree,
  nodes,
  positions = rep(0, length(nodes)),
  singleton = FALSE,
  tipBranchLengths = 0.01,
  nodeLabels = NULL,
  tipLabels = NULL
)
```

Arguments

`tree`	a phylo object
`nodes`	an integer vector denoting the terminating nodes of the edges on which a singleton node is to be inserted. This vector should not have duplicated nodes - if there is a need to insert two or more singleton nodes at distinct positions of the same edge, this should be done by calling the function several times with the longest position first and so on .
`positions`	a positive numeric vector of the same length as nodes denoting the root-ward distances from nodes at which the singleton nodes should be inserted. For PCMTreeInsertTipsOrSingletons this can contains 0's and is set by default to rep(0, length(nodes)).
`epoch`	a numeric indicating a distance from the root at which a singleton node should be inserted in all lineages that are alive at that time.
`minLength`	a numeric indicating the minimum allowed branch-length after dividing a branch by insertion of a singleton nodes. No singleton node is inserted if this would result in a branch shorter than 'minLength'. Note that this condition is checked only in 'PCMTreeInsertSingletonsAtEpoch'.
`singleton`	(PCMTreeInsertTipsOrSingletons only) a logical indicating if a singleton node should be inserted and no tip node should be inserted.

`tipBranchLengths`	(PCMTreeInsertTipsOrSingletons only) positive numeric vector of the length of `nodes`, denoting the lengths of the new edges leading to tips.
`nodeLabels`	(PCMTreeInsertSingletons and PCMTreeInsertTipsOrSingletons) a character vector of the same length as `nodes`, indicating the names of the newly inserted nodes. These names are ignored where `positions` is 0. This argument is optional and default node labels will be assigned if this is not specified or set to NULL. If specified, then it should not contain node-labels already present in the tree.
`tipLabels`	(PCMTreeInsertTipsOrSingletons only) a character vector of the same length as `nodes` of the new tip-labels. This argument is optional and default tip labels will be assigned if this is not specified or set to NULL. If specified, then it should not contain tip-labels already present in the tree.

Value

a modified copy of tree.

Functions

- `PCMTreeInsertSingletonsAtEpoch`:
- `PCMTreeInsertTipsOrSingletons`:

See Also

`PCMTreeEdgeTimes` `PCMTreeLocateEpochOnBranches` `PCMTreeLocateMidpointsOnBranches`

Examples

```
set.seed(1, kind = "Mersenne-Twister", normal.kind = "Inversion")
tree <- PCMTree(ape::rtree(25))
PCMTreeSetPartRegimes(
  tree, c(`26`="a", `28`="b", `45`="c", `47`="d"), setPartition = TRUE)

if(requireNamespace("ggtree"))
PCMTreePlot(
  tree,
  palette=c(a = "red", b = "green", c = "blue", d = "magenta")) +
  ggtree::geom_nodelab(angle = 45) + ggtree::geom_tiplab(angle = 45)

cbind(tree$edge, PCMTreeEdgeTimes(tree))

id47 <- PCMTreeMatchLabels(tree, "47")
length47 <- PCMTreeGetBranchLength(tree, id47)

# insert a singleton at 0.55 (root-ward) from node 47
tree <- PCMTreeInsertSingletons(tree, nodes = "47", positions = (length47/2))

if(requireNamespace("ggtree"))
PCMTreePlot(
  tree,
  palette=c(a = "red", b = "green", c = "blue", d = "magenta")) +
  ggtree::geom_nodelab(angle = 45) + ggtree::geom_tiplab(angle = 45)

# this fails, because the branch leading to node "47" is shorter now (0.55).
ggplot2::should_stop(
  tree <- PCMTreeInsertSingletons(
    tree, nodes = "47", positions= 2* length47 / 3))

# the tree is the same

if(requireNamespace("ggtree"))
PCMTreePlot(
  tree, palette=c(a = "red", b = "green", c = "blue", d = "magenta")) +
  ggtree::geom_nodelab(angle = 45) + ggtree::geom_tiplab(angle = 45)

# we can insert at a position within the edge:
tree <- PCMTreeInsertSingletons(tree, nodes = "47", positions = length47/3)

if(requireNamespace("ggtree"))
PCMTreePlot(
  tree, palette=c(a = "red", b = "green", c = "blue", d = "magenta")) +
  ggtree::geom_nodelab(angle = 45) + ggtree::geom_tiplab(angle = 45)


# Insert singletons at all branches crossing a given epoch. This will skip
# inserting singleton nodes where the resulting branches would be shorter
# than 0.1.
tree <- PCMTreeInsertSingletonsAtEpoch(tree, 2.3)

if(requireNamespace("ggtree"))
PCMTreePlot(
  tree, palette=c(a = "red", b = "green", c = "blue", d = "magenta")) +
  ggtree::geom_nodelab(angle = 45) + ggtree::geom_tiplab(angle = 45)

# Insert singletons at all branches crossing a given epoch
tree <- PCMTreeInsertSingletonsAtEpoch(tree, 2.3, minLength = 0.001)

if(requireNamespace("ggtree"))
PCMTreePlot(
  tree,
  palette=c(a = "red", b = "green", c = "blue", d = "magenta")) +
  ggtree::geom_nodelab(angle = 45) + ggtree::geom_tiplab(angle = 45)
```

`PCMTreeJumps` *Jumps in modeled traits associated with branches in a tree*

Description

Jumps in modeled traits associated with branches in a tree

Usage

```
PCMTreeJumps(tree)
```

Arguments

`tree`	a phylo object

Value

an integer vector of 0's and 1's with entries corresponding to the denoting if a jump took place at the beginning of a branch.

`PCMTreeListAllPartitions` *A list of all possible (including recursive) partitions of a tree*

Description

A list of all possible (including recursive) partitions of a tree

Usage

```
PCMTreeListAllPartitions(
  tree,
  minCladeSize,
  skipNodes = character(),
  tableAncestors = NULL,
  verbose = FALSE
)
```

Arguments

`tree`	a phylo object with set labels for the internal nodes
`minCladeSize`	integer indicating the minimum number of tips allowed in one part.
`skipNodes`	an integer or character vector indicating the ids or labels of nodes that should not be used as partition nodes. By default, this is an empty character vector.
`tableAncestors`	NULL (default) or an integer matrix returned by a previous call to `PCMTreeTableAncestors(tree)`.
`verbose`	a logical indicating if informative messages should be printed to the console.

Value

a list of integer vectors.

Examples

```
set.seed(1, kind = "Mersenne-Twister", normal.kind = "Inversion")
tree <- PCMTree(ape::rtree(10))

if(requireNamespace("ggtree"))
PCMTreePlot(tree) + ggtree::geom_nodelab() + ggtree::geom_tiplab()

# list of all partitions into parts of at least 4 tips
PCMTreeListAllPartitions(tree, 4)

# list of all partitions into parts of at least 3 tips
PCMTreeListAllPartitions(tree, 3)

# list all partitions into parts of at least 3 tips, excluding the partitions
# where node 16 is one of the partition nodes:
PCMTreeListAllPartitions(tree, minCladeSize = 3, skipNodes = "16")
```

PCMTreeListCladePartitions

A list of all possible clade partitions of a tree with a number of splitting nodes

---

Description

Each subset of nNodes distinct internal or tip nodes defines a partition of the branches of the tree into nNodes+1 blocks called parts. This function generates partitions where each part has nNodes splitting nodes and contains at least minCladeSize tips.

Usage

```
PCMTreeListCladePartitions(
  tree,
  nNodes,
  minCladeSize = 0,
  skipNodes = character(0),
  tableAncestors = NULL,
  countOnly = FALSE,
  verbose = FALSE
)
```

Arguments

tree	a phylo object
nNodes	an integer giving the number of partitioning nodes. There would be nNodes+1 blocks in each partition (see details).
minCladeSize	integer indicating the minimum number of tips allowed in a clade.

`skipNodes`	an integer or character vector indicating the ids or labels of nodes that should not be used as partition nodes. By default, this is an empty character vector.
`tableAncestors`	NULL (default) or an integer matrix returned by a previous call to `PCMTreeTableAncestors(tree)`.
`countOnly`	logical indicating if the only the number of partitions should be returned.
`verbose`	a logical indicating if informative messages should be printed to the console.

Value

a list of integer `nNodes`-vectors. By default a full traversal of all partitions is done. It is possible to truncate the search to a limited number of partitions by setting the option PCMBase.MaxLengthListCladePartitions to a finite positive integer.

See Also

`PCMOptions`

`PCMTreeListDescendants`

A list of the descendants for each node in a tree

Description

A list of the descendants for each node in a tree

Usage

```
PCMTreeListDescendants(tree, tableAncestors = PCMTreeTableAncestors(tree))
```

Arguments

`tree`	a phylo object
`tableAncestors`	an integer matrix resulting from a call to PCMTreeTableAncestors(tree).

Details

This function has time and memory complexity O(M^2), where M is the number of nodes in the tree. It can take several minutes and gigabytes of memory on trees of more than 10000 tips.

Value

a list with unnamed elements in the order of nodes in the tree. Each element is an integer vector containing the descendant nodes (in increasing order) of the node identified by its index-number in the list.

`PCMTreeListRootPaths` *A list of the path to the root from each node in a tree*

Description

A list of the path to the root from each node in a tree

Usage

```
PCMTreeListRootPaths(tree, tableAncestors = PCMTreeTableAncestors(tree))
```

Arguments

`tree`	a phylo object
`tableAncestors`	an integer matrix resulting from a call to PCMTreeTableAncestors(tree).

Details

This function has time and memory complexity O(M^2), where M is the number of nodes in the tree. It can take several minutes and gigabytes of memory on trees of more than 10000 tips.

Value

a list with unnamed elements in the order of nodes in the tree. Each element is an integer vector containing the ancestors nodes on the path from the node (i) to the root of the tree in that order (the first element in the vector is the parent node of i and so on).

`PCMTreeLocateEpochOnBranches` *Find the crossing points of an epoch-time with each lineage of a tree*

Description

Find the crossing points of an epoch-time with each lineage of a tree

Usage

```
PCMTreeLocateEpochOnBranches(tree, epoch)
```

Arguments

`tree`	a phylo
`epoch`	a positive numeric indicating tip-ward distance from the root

Value

a named list with an integer vector element "nodes" denoting the ending nodes for each branch crossing epoch and numeric vector element "positions" denoting the root-ward offset from each node in nodes.

`PCMTreeLocateMidpointsOnBranches` *Find the middle point of each branch longer than a threshold*

Description

Find the middle point of each branch longer than a threshold

Usage

```
PCMTreeLocateMidpointsOnBranches(tree, threshold = 0)
```

Arguments

`tree`	a phylo
`threshold`	a positive numeric; only branches longer than threshold will be returned; Default 0.

Value

a named list with an integer vector element "nodes" denoting the ending nodes for each branch crossing epoch and numeric vector element "positions" denoting the root-ward offset from each node in nodes.

`PCMTreeMatchLabels` *Get the node numbers associated with tip- or node-labels in a tree*

Description

Get the node numbers associated with tip- or node-labels in a tree

Usage

```
PCMTreeMatchLabels(tree, labels, stopIfNotFound = TRUE)
```

Arguments

`tree`	a phylo object
`labels`	a character vector with valid tip or node labels from tree
`stopIfNotFound`	logical indicating if an error should be raised in case a label has not been found in the tree labels. Default: TRUE

Value

an integer vector giving the tip- or node- integer indices corresponding to labels. If stopIfNotFound is set to FALSE, this vector may contain NAs for the labels that were not found.

Examples

```
set.seed(1, kind = "Mersenne-Twister", normal.kind = "Inversion")
PCMTreeMatchLabels(PCMTree(ape::rtree(20)), c("t1", "t15", "21", "39"))
PCMTreeMatchLabels(PCMTree(ape::rtree(20)), c("t1", "45"), stopIfNotFound = FALSE)
```

PCMTreeMatrixNodesInSamePart *Which couples from a given set of nodes in a tree belong to the same part?*

Description

Which couples from a given set of nodes in a tree belong to the same part?

Which couples from a given set of nodes in a tree belong to the same regime?

Usage

```
PCMTreeMatrixNodesInSamePart(
  tree,
  nodes = seq_len(PCMTreeNumNodes(tree)),
  upperTriangle = TRUE,
  returnVector = TRUE
)

PCMTreeMatrixNodesInSameRegime(
  tree,
  nodes = seq_len(PCMTreeNumNodes(tree)),
  upperTriangle = TRUE,
  returnVector = TRUE
)
```

Arguments

`tree`	a PCMTree object or a phylo object.
`nodes`	an integer vector of length L >= 2 denoting a set of nodes in the tree.
`upperTriangle`	logical indicating if all duplicated entries and diagonal entries should be set to NA (by default TRUE).
`returnVector`	logical indicating if a vector instead of a matrix should be returned (corresponding to calling as.vector on the resulting matrix and removing NAs). Default: TRUE

Value

a L x L logical matrix with TRUE on the diagonal and for each couple of tips that belong to the same part or regime. If returnVector is TRUE (default) only a vector of the non-NA entries will be returned.

a L x L logical matrix with TRUE on the diagonal and for each couple of tips that belong to the same part or regime. If returnVector is TRUE (default) only a vector of the non-NA entries will be returned.

Examples

```
set.seed(1, kind = "Mersenne-Twister", normal.kind = "Inversion")
tree <- PCMTree(ape::rtree(8))
PCMTreeMatrixNodesInSamePart(tree, returnVector = FALSE)

PCMTreeSetPartition(tree, c(10, 12))
PCMTreeMatrixNodesInSamePart(tree, returnVector = FALSE)

PCMTreeMatrixNodesInSamePart(tree)
PCMTreeMatrixNodesInSamePart(tree, seq_len(PCMTreeNumTips(tree)))
PCMTreeMatrixNodesInSamePart(
  tree, seq_len(PCMTreeNumTips(tree)), returnVector = FALSE)
```

```
set.seed(1, kind = "Mersenne-Twister", normal.kind = "Inversion")
tree <- PCMTree(ape::rtree(8))
PCMTreeMatrixNodesInSamePart(tree, returnVector = FALSE)

PCMTreeSetPartition(tree, c(10, 12))
PCMTreeMatrixNodesInSamePart(tree, returnVector = FALSE)

PCMTreeMatrixNodesInSamePart(tree)
PCMTreeMatrixNodesInSamePart(tree, seq_len(PCMTreeNumTips(tree)))
PCMTreeMatrixNodesInSamePart(
  tree, seq_len(PCMTreeNumTips(tree)), returnVector = FALSE)
```

`PCMTreeNearestNodesToEpoch`

Find the nearest node to a given time from the root (epoch) on each lineage crossing this epoch

---

Description

Find the nearest node to a given time from the root (epoch) on each lineage crossing this epoch

Usage

```
PCMTreeNearestNodesToEpoch(tree, epoch)
```

Arguments

`tree`	a phylo
`epoch`	a non-negative numeric

Value

an integer vector

`PCMTreeNodeTimes` *Calculate the time from the root to each node of the tree*

Description

Calculate the time from the root to each node of the tree

Usage

```
PCMTreeNodeTimes(tree, tipsOnly = FALSE)
```

Arguments

`tree`	an object of class phylo
`tipsOnly`	Logical indicating whether the returned results should be truncated only to the tips of the tree.

Value

A vector of size the number of nodes in the tree (tips, root, internal) containing the time from the root to the corresponding node in the tree.

`PCMTreeNumNodes` *Number of all nodes in a tree*

Description

Number of all nodes in a tree

Usage

```
PCMTreeNumNodes(tree)
```

Arguments

`tree`	a phylo object

Details

Wrapper for nrow(tree$edge) + 1

Value

the number of nodes in tree including root, internal and tips.

`PCMTreeNumParts` *Number of unique parts on a tree*

Description

Number of unique parts on a tree

Usage

```
PCMTreeNumParts(tree)
```

Arguments

`tree`	a phylo object

Value

the number of different parts encountered on the tree branches

---

`PCMTreeNumTips` *Wrapper for length(tree$tip.label)*

Description

Wrapper for length(tree$tip.label)

Usage

```
PCMTreeNumTips(tree)
```

Arguments

`tree`	a phylo object

Value

the number of tips in tree

`PCMTreePlot` *Plot a tree with parts and regimes assigned to these parts*

Description

Plot a tree with parts and regimes assigned to these parts

Usage

```
PCMTreePlot(
  tree,
  palette = PCMColorPalette(PCMNumRegimes(tree), PCMRegimes(tree)),
  ...
)
```

Arguments

`tree`	a PCMTree or a phylo object.
`palette`	a named vector of colors corresponding to the regimes in tree
`...`	Arguments passed to ggtree, e.g. layout = 'fan', open.angle = 8, size=.25.

Note

This function requires that the ggtree package is installed. At the time of releasing this version the ggtree package is not available on CRAN. Check the ggtree homepage for instruction on how to install this package: .

`PCMTreePostorder` *Post-order tree traversal*

Description

Post-order tree traversal

Usage

```
PCMTreePostorder(tree)
```

Arguments

`tree`	a phylo object with possible singleton nodes (i.e. internal nodes with one daughter node)

Value

a vector of indices of edges in tree$edge in post-order.

`PCMTreePreorder` *Pre-order tree traversal*

Description

Pre-order tree traversal

Usage

```
PCMTreePreorder(tree)
```

Arguments

`tree`	a phylo object with possible singleton nodes (i.e. internal nodes with one daughter node)

Value

a vector of indices of edges in tree$edge in pre-order.

`PCMTreeSetLabels` *Set tip and internal node labels in a tree*

Description

Set tip and internal node labels in a tree

Usage

```
PCMTreeSetLabels(
  tree,
  labels = as.character(1:PCMTreeNumNodes(tree)),
  inplace = TRUE
)
```

Arguments

`tree`	a phylo object or a PCMTree object. If this is a PCMTree object, the internal edge.part and part.regime members will be updated accordingly.
`labels`	a character vector in the order 1:PCMTreeNumNodes(tree) as denoted in the tree$edge matrix.
`inplace`	a logical indicating if the change should be done in place on the object in the calling environment (in this case tree must not be a temporary object, e.g. returned by another function call). Default is TRUE.

Value

if inplace is FALSE, a copy of tree with set or modified tree$tip.label and tree$node.label. If the original tree has a member edge.part, the returned tree has tree$edge.part and tree$part.regime updated. If inplace is TRUE (the default), nothing is returned and the above changes are made directly on the input tree.

See Also

PCMTree

Examples

```
tree <- ape::rtree(5)
tree$tip.label
# the following three are NULLs
tree$node.label
tree$edge.part
tree$part.regime


tree <- PCMTree(tree)
PCMTreeSetPartition(tree, c(6, 8))
tree$tip.label
tree$node.label
tree$edge.part
tree$part.regime

PCMTreeSetLabels(
  tree, labels = paste0(c(rep("t", 5), rep("n", 4)), PCMTreeGetLabels(tree)))
PCMTreeGetLabels(tree)
tree$tip.label
tree$node.label
tree$edge.part
tree$part.regime
```

PCMTreeSetPartition *Set a partition of a tree by specifying the partition nodes*

Description

Set a partition of a tree by specifying the partition nodes

Usage

```
PCMTreeSetPartition(tree, nodes = c(PCMTreeNumTips(tree) + 1L), inplace = TRUE)
```

Arguments

`tree`	a PCMTree object.
`nodes`	a character vector containing tip or node labels or an integer vector denoting tip or internal nodes in tree - the parts change at the start of the branches leading to these nodes. Default: c(PCMTreeNumTips(tree) + 1L).
`inplace`	a logical indicating if the change should be done to the tree in the calling environment (TRUE) or a copy of the tree with set edge.part member should be returned (FALSE). Default is TRUE.

Value

If inplace is TRUE nothing, otherwise a copy of the tree with set edge.part member.

See Also

`PCMTreeGetPartition`

`PCMTree`

Examples

```
set.seed(1, kind = "Mersenne-Twister", normal.kind = "Inversion")
tree <- PCMTree(ape::rtree(8))
PCMTreeSetLabels(tree, paste0("x", PCMTreeGetLabels(tree)))
PCMTreeGetPartition(tree)
PCMTreeGetPartNames(tree)
PCMTreeGetPartRegimes(tree)

if(requireNamespace("ggtree"))
PCMTreePlot(tree) + ggtree::geom_nodelab() + ggtree::geom_tiplab()

tree <- PCMTreeSetPartition(tree, c(12, 14), inplace = FALSE)
PCMTreeGetPartition(tree)
PCMTreeGetPartNames(tree)
PCMTreeGetPartRegimes(tree)

if(requireNamespace("ggtree"))
PCMTreePlot(tree) + ggtree::geom_nodelab() + ggtree::geom_tiplab()

# reset the partition to a default one, where there is only one part:
PCMTreeSetPartition(tree)

PCMTreeGetPartition(tree)
PCMTreeGetPartNames(tree)
PCMTreeGetPartRegimes(tree)
if(requireNamespace("ggtree"))
PCMTreePlot(tree) + ggtree::geom_nodelab() + ggtree::geom_tiplab()


# reset the labels to the default labels which are character representations
# of the node ids
```

```
PCMTreeSetLabels(tree)
PCMTreeGetPartition(tree)
PCMTreeGetPartNames(tree)
PCMTreeGetPartRegimes(tree)
```

PCMTreeSetPartRegimes *Set regimes for the parts in a tree*

Description

Set regimes for the parts in a tree

Usage

```
PCMTreeSetPartRegimes(tree, part.regime, setPartition = FALSE, inplace = TRUE)
```

Arguments

tree	a PCMTree object.
part.regime	a named vector containing regimes to be assigned to some of or to each of the parts in the tree.
setPartition	a logical indicating if the partition of the tree should be set as well. If this argument is set to TRUE, the names of part.regime are passed as the nodes argument in a call to `PCMTreeSetPartition`. Default: FALSE.
inplace	a logical indicating if the change should be done to the tree in the calling environment (TRUE) or a copy of the tree with set edge.part member should be returned (FALSE). Default is TRUE.

Value

If inplace is TRUE nothing, otherwise a copy of the tree with set edge.part and part.regime members.

See Also

PCMTree

Examples

```
tree <- PCMTree(ape::rtree(25))
PCMTreeGetPartition(tree)
PCMTreeGetPartRegimes(tree)
PCMTreeGetPartNames(tree)

PCMTreeSetPartRegimes(tree, c(`26` = 2))
PCMTreeGetPartition(tree)
PCMTreeGetPartRegimes(tree)
PCMTreeGetPartNames(tree)
```

```
PCMTreeSetPartRegimes(tree, c(`26` = "global-regime"))
PCMTreeGetPartition(tree)
PCMTreeGetPartRegimes(tree)
PCMTreeGetPartNames(tree)

# This should fail because no partition with nodes 26, 28 and 41 has been
# done.
ggplot2::should_stop(
  PCMTreeSetPartRegimes(tree, c(`26` = "a", `28` = "b", `41` = "c")))
# This should succeed and change the partition as well as regime assignment
PCMTreeSetPartRegimes(
  tree, c(`26` = "a", `28` = "b", `41` = "c"), setPartition = TRUE)
PCMTreeGetPartition(tree)
PCMTreeGetPartRegimes(tree)
PCMTreeGetPartNames(tree)



set.seed(1, kind = "Mersenne-Twister", normal.kind = "Inversion")
# number of tips
N <- 40

# tree with one regime
tree.a <- ape::rtree(N)

tree.a <- PCMTree(tree.a)

PCMTreeSetPartRegimes(
  tree.a,
  part.regime = structure("a", names = as.character(N+1L)),
  setPartition = TRUE,
  inplace = TRUE)



if(requireNamespace("ggtree"))
PCMTreePlot(tree.a) + ggtree::geom_nodelab() + ggtree::geom_tiplab()

tree.ab <- tree.a
PCMTreeSetPartRegimes(
  tree.ab,
  part.regime = structure(c("a", "b"), names = as.character(c(N+1L, N+31L))),
  setPartition = TRUE,
  inplace = TRUE)

if(requireNamespace("ggtree"))
PCMTreePlot(tree.ab) + ggtree::geom_nodelab() + ggtree::geom_tiplab()
```

PCMTreeSetRegimesForEdges

Set the regime for each individual edge in a tree explicitly

Description

Set the regime for each individual edge in a tree explicitly

Usage

```
PCMTreeSetRegimesForEdges(tree, regimes, inplace = TRUE)
```

Arguments

`tree`	a PCMTree or a phylo object.
`regimes`	a vector of the length equal to ‘nrow(tree$edge)‘.
`inplace`	a logical indicating if the change should be done within the tree in the calling environment or a copy of the tree with modified regime assignment should be returned.

Value

if inplace is TRUE, nothing, otherwise a modified copy of tree.

Note

Calling this function overwrites the current partitioning of the tree.

Examples

```
set.seed(1, kind = "Mersenne-Twister", normal.kind = "Inversion")
tree <- ape::rtree(10)
regimes <- sample(letters[1:3], nrow(tree$edge), replace = TRUE)
PCMTreeSetRegimesForEdges(tree, regimes)

if(requireNamespace("ggtree"))
PCMTreePlot(tree)
```

PCMTreeSplitAtNode *Slit a tree at a given internal node into a clade rooted at this node and the remaining tree after dropping this clade*

Description

Slit a tree at a given internal node into a clade rooted at this node and the remaining tree after dropping this clade

Usage

```
PCMTreeSplitAtNode(
  tree,
  node,
  tableAncestors = PCMTreeTableAncestors(tree),
  X = NULL
)
```

Arguments

`tree`	a PCMTree object.
`node`	an integer or character indicating a root, internal or tip node
`tableAncestors`	an integer matrix returned by a previous call to PCMTreeTableAncestors(tree) or NULL.
`X`	an optional k x N matrix with trait value vectors for each tip in tree.

Details

In the current implementation, the edge.jump and edge.part members of the tree will be discarded and not present in the clade.

Value

A list containing two named phylo objects:

clade The subtree (clade) starting at `node`.

Xclade The portion of X attributable to the tips in clade; NULL if X is NULL.

rest The tree resulting after dropping all tips in the clade.

Xrest The portion of X attributable to the tips in rest; NULL if X is NULL.

Examples

```
set.seed(1, kind = "Mersenne-Twister", normal.kind = "Inversion")
tree <- PCMTree(ape::rtree(25))

if(requireNamespace("ggtree"))
PCMTreePlot(tree) + ggtree::geom_nodelab(angle = 45) +
  ggtree::geom_tiplab(angle = 45)

spl <- PCMTreeSplitAtNode(tree, 28)

if(requireNamespace("ggtree"))
PCMTreePlot(PCMTree(spl$clade)) + ggtree::geom_nodelab(angle = 45) +
  ggtree::geom_tiplab(angle = 45)

if(requireNamespace("ggtree"))
PCMTreePlot(PCMTree(spl$rest)) + ggtree::geom_nodelab(angle = 45) +
  ggtree::geom_tiplab(angle = 45)
```

`PCMTreeTableAncestors` *A matrix (table) of ancestors/descendants for each node in a tree*

Description

A matrix (table) of ancestors/descendants for each node in a tree

Usage

```
PCMTreeTableAncestors(tree, preorder = PCMTreePreorder(tree))
```

Arguments

`tree`	a phylo object
`preorder`	an integer vector returned by a previous call to `PCMTreePreorder(tree)`. Default `PCMTreePreorder(tree)`.

Details

This function has time and memory complexity O(M^2), where M is the number of nodes in the tree. It can take several minutes and gigabytes of memory on trees of more than 10000 tips.

Value

an integer square matrix of size M x M where M is the number of nodes in the tree. Element j on row i is 0 if j is not an ancestor of i or a positive integer equal to the position of j on the path from the root to i if j is an ancestor of i.

`PCMTreeToString` *A character representation of a phylo object.*

Description

A character representation of a phylo object.

Usage

```
PCMTreeToString(tree, includeLengths = FALSE, includePartition = FALSE)
```

Arguments

`tree`	a phylo object.
`includeLengths`	logical. Default: FALSE.
`includePartition`	logical. Default: FALSE.

Value

a character string.

`PCMTreeVCV` *Phylogenetic Variance-covariance matrix*

Description

This is a simplified wrapper for ape's `vcv` function. Setting the runtime option PCMBase.UsePCMVarForVCV to TRUE will switch to a computation of the matrix using the function `PCMVar`.

Usage

```
PCMTreeVCV(tree)
```

Arguments

`tree`	a phylo object

Value

a N x N matrix. Assuming a BM model of evolution, this is a matrix in which element (i,j) is equal to the shared root-distance of the nodes i and j.

See Also

`vcv` `PCMVar` `PCMOptions`

`PCMUnfixParameter` *Unfix a parameter in a PCM model*

Description

Unfix a parameter in a PCM model

Usage

```
PCMUnfixParameter(model, name)
```

Arguments

`model`	a PCM object
`name`	a character string

Value

a copy of the model with removed class '_Fixed' from the class of the parameter `name`

`PCMVar` *Expected variance-covariance matrix for each couple of tips (i,j)*

Description

Expected variance-covariance matrix for each couple of tips (i,j)

Usage

```
PCMVar(
  tree,
  model,
  W0 = matrix(0, PCMNumTraits(model), PCMNumTraits(model)),
  SE = matrix(0, PCMNumTraits(model), PCMTreeNumTips(tree)),
  metaI = PCMInfo(NULL, tree, model, verbose = verbose),
  internal = FALSE,
  diagOnly = FALSE,
  verbose = FALSE
)
```

Arguments

`tree`	a phylo object with N tips.
`model`	an S3 object specifying both, the model type (class, e.g. "OU") as well as the concrete model parameter values at which the likelihood is to be calculated (see also Details).
`W0`	a numeric matrix denoting the initial k x k variance covariance matrix at the root (default is the k x k zero matrix).
`SE`	a k x N matrix specifying the standard error for each measurement in X. Alternatively, a k x k x N cube specifying an upper triangular k x k factor of the variance covariance matrix for the measurement error for each tip `i=1, ..., N`. When `SE` is a matrix, the k x k measurement error variance matrix for a tip `i` is calculated as `VE[, , i] <- diag(SE[, i] * SE[, i], nrow = k)`. When `SE` is a cube, the way how the measurement variance matrix for a tip `i` is calculated depends on the runtime option `PCMBase.Transpose.Sigma_x` as follows: **if** `getOption("PCMBase.Transpose.Sigma_x", FALSE) == FALSE` **(default):** VE[, , i] <- SE[, , i] %*% t(SE[, , i]) **if** `getOption("PCMBase.Transpose.Sigma_x", FALSE) == TRUE`**:** VE[, , i] <- t(SE[, , i]) %*% SE[, , i] Note that the above behavior is consistent with the treatment of the model parameters `Sigma_x`, `Sigmae_x` and `Sigmaj_x`, which are also specified as upper triangular factors. Default: `matrix(0.0, PCMNumTraits(model), PCMTreeNumTips(tree))`.
`metaI`	a list returned from a call to `PCMInfo(X, tree, model, SE)`, containing meta-data such as N, M and k. Alternatively, this can be a character string naming a function or a function object that returns such a list, e.g. the function`PCMInfo` or the function `PCMInfoCpp` from the `PCMBaseCpp` package.
`internal`	a logical indicating if the per-node variance-covariances matrices for the internal nodes should be returned (see Value). Default FALSE.
`diagOnly`	a logical indicating if only the variance blocks for the nodes should be calculated. By default this is set to FALSE, meaning that the co-variances are calculated for all couples of nodes.
`verbose`	logical indicating if some debug-messages should printed.

Value

If internal is FALSE, a (k x N) x (k x N) matrix W, such that k x k block `W[((i-1)*k)+(1:k), ((j-1)*k)+(1:k)]` equals the expected covariance matrix between tips i and j. Otherwise, a list with an element 'W' as described above and a k x M matrix element 'Wii' containing the per-node variance covariance matrix for each node: The k x k block `Wii[, (i-1)*k + (1:k)]` represents the variance covariance matrix for node i.

Examples

```
# a Brownian motion model with one regime
modelBM <- PCM(model = "BM", k = 2)
# print the model
modelBM
```

```
# assign the model parameters at random: this will use uniform distribution
# with boundaries specified by PCMParamLowerLimit and PCMParamUpperLimit
# We do this in two steps:
# 1. First we generate a random vector. Note the length of the vector equals PCMParamCount(modelBM)
randomParams <- PCMParamRandomVecParams(modelBM, PCMNumTraits(modelBM), PCMNumRegimes(modelBM))
randomParams
# 2. Then we load this random vector into the model.
PCMParamLoadOrStore(modelBM, randomParams, 0, PCMNumTraits(modelBM), PCMNumRegimes(modelBM), TRUE)

# create a random tree of 10 tips
tree <- ape::rtree(10)
covMat <- PCMVar(tree, modelBM)
```

PCMVarAtTime *Calculate the variance covariance k x k matrix at time t, under a PCM model*

Description

Calculate the variance covariance k x k matrix at time t, under a PCM model

Usage

```
PCMVarAtTime(
  t,
  model,
  W0 = matrix(0, PCMNumTraits(model), PCMNumTraits(model)),
  SE = matrix(0, PCMNumTraits(model), PCMNumTraits(model)),
  regime = PCMRegimes(model)[1L],
  verbose = FALSE
)
```

Arguments

t	positive numeric denoting time
model	a PCM model object
W0	a numeric matrix denoting the initial k x k variance covariance matrix at the root (default is the k x k zero matrix).
SE	a k x k matrix specifying the upper triangular factor of the measurement error variance-covariance matrix. The product SE Default: SE = matrix(0.0, PCMNumTraits(model), PCMNumTraits(model)).
regime	an integer or a character denoting the regime in model for which to do the calculation; Defaults to PCMRegimes(model)[1L], meaning the first regime in the model.
verbose	a logical indicating if (debug) messages should be written on the console (Defaults to FALSE).

Value

A numeric k x k matrix

Examples

```
# a Brownian motion model with one regime
modelBM <- PCM(model = "BM", k = 2)
# print the model
modelBM
# assign the model parameters at random: this will use uniform distribution
# with boundaries specified by PCMParamLowerLimit and PCMParamUpperLimit
# We do this in two steps:
# 1. First we generate a random vector. Note the length of the vector equals PCMParamCount(modelBM)
randomParams <- PCMParamRandomVecParams(modelBM, PCMNumTraits(modelBM), PCMNumRegimes(modelBM))
randomParams
# 2. Then we load this random vector into the model.
PCMParamLoadOrStore(modelBM, randomParams, 0, PCMNumTraits(modelBM), PCMNumRegimes(modelBM), TRUE)

# PCMVarAtTime(1, modelBM)

# note that the variance at time 0 is not the 0 matrix because the model has a non-zero
# environmental deviation
PCMVarAtTime(0, modelBM)
```

RequireSuggestedPackages

Check if all packages listed in Suggests are available

Description

Check if all packages listed in Suggests are available

Usage

```
RequireSuggestedPackages()
```

Value

logical TRUE if suggested packages are installed and can be loaded; FALSE otherwise

TruePositiveRate *True positive rate of a set of binary predictions against their trues*

Description

Let the set of predictions be described by a logical vector ‘pred‘, and let the corresponding trues by described in a logical vector ‘true‘ of the same length. Then, the true positive rate is given by the expression: `sum(pred & true)/sum(true)`. The false positive rate is given by the expression: `sum(pred & !true)/sum(!true)`. If these expressions do not give a finite number, `NA_real_` is returned.

Usage

```
TruePositiveRate(pred, true)

FalsePositiveRate(pred, true)
```

Arguments

`pred, true`	vectors of the same positive length that can be converted to logical.

Value

a double between 0 and 1 or `NA_real_` if the result is not a finite number.

Examples

```
TruePositiveRate(c(1,0,1,1), c(1,1,0,1))
TruePositiveRate(c(0,0,0,0), c(1,1,0,1))
TruePositiveRate(c(1,1,1,1), c(1,1,0,1))
FalsePositiveRate(c(1,0,1,1), c(1,1,0,1))
FalsePositiveRate(c(0,0,0,0), c(1,1,0,1))
FalsePositiveRate(c(1,1,1,1), c(1,1,0,1))
TruePositiveRate(c(1,0,1,1), c(0,0,0,0))
FalsePositiveRate(c(1,0,1,1), c(1,1,1,1))
```

UpperTriFactor *Upper triangular factor of a symmetric positive definite matrix*

Description

This function is an analog to the Cholesky decomposition.

Usage

```
UpperTriFactor(Sigma)
```

Arguments

`Sigma`	A symmetric positive definite k x k matrix that can be passed as argument to `chol`.

Value

an upper triangular matrix Sigma_x, such that Sigma = Sigma_x %*% t(Sigma_x)

See Also

`chol`;

the option `PCMBase.Transpose.Sigma_x` in `PCMOptions`.

Examples

```
# S is a symmetric positive definite matrix
M<-matrix(rexp(9),3,3); S <- M %*% t(M)

# This should return a zero matrix:
UpperTriFactor(S) %*% t(UpperTriFactor(S)) - S

# This should return a zero matrix too:
t(chol(S)) %*% chol(S) - S

# Unless S is diagonal, in the general case, this will return a
# non-zero matrix:
chol(S) %*% t(chol(S)) - S
```

`White` *White Gaussian PCM ignoring phylogenetic history*

Description

White model ignoring phylogenetic history, treating trait values as independent samples from a k-variate Gaussian.

Details

Calculating likelihoods for this model does not work if the global option PCMBase.Singular.Skip is set to FALSE.

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