Package ‘BAMMtools’

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Type Package

Title Analysis and Visualization of Macroevolutionary Dynamics on Phylogenetic Trees

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Depends ape

Description Provides functions for analyzing and visualizing complex macroevolutionary dynamics on phylogenetic trees. It is a companion package to the command line program BAMM (Bayesian Analysis of Macroevolutionary Mixtures) and is entirely oriented towards the analysis, interpretation, and visualization of evolutionary rates. Functionality includes visualization of rate shifts on phylogenies, estimating evolutionary rates through time, comparing posterior distributions of evolutionary rates across clades, comparing diversification models using Bayes factors, and more.

License GPL (>= 2)

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Bayesian Analysis of Macroevolutionary Mixtures (BAMM)

Description

An R package for the analysis and visualization of complex macroevolutionary dynamics. Functions in **BAMMtools** are oriented entirely around analysis of results obtained using the **BAMM** software (bamm-project.org).
Details
addBAMMlegend

Add a color legend to a phylo-rate plot

Description
Add a legend to a phylorate plot, with greater manual control.

Usage
addBAMMlegend(x, corners = c(0,1,0,1), side = 3, nTicks = 2, axisOffset = 0.4, ...)

Arguments
- `x`: a plot.bammdata object.
- `corners`: coordinates for the corners of the bar legend c(xmin, xmax, ymin, ymax).
- `side`: side for tick marks, see `axis` documentation.
- `nTicks`: number of tick marks, besides of min and max.
- `axisOffset`: distance from color bar for labels.
- `...`: additional parameters to be passed to `axis`.

Value
Legend is plotted. Nothing is returned.
addBAMMshifts

Author(s)

Pascal Title

See Also

Requires an object created with plot.bammdata.

Examples

data(whales, events.whales)
ephy <- getEventData(whales, events.whales, burnin=0.25)

x <- plot.bamdata(ephy, lwd=2)
axis(1); axis(2)
addBAMMlegend(x, corners = c(-1, -0.5, 50, 80), nTicks = 4, side = 4, las = 1)
addBAMMlegend(x, corners = c(5, 20, 60, 61), nTicks = 4, side = 3, las = 1, cex.axis = 0.7)

#addBAMMlegend also automatically detects the use of color.interval
data(primates, events.primates)
ephy <- getEventData(primates, events.primates, burnin=0.25, type = 'trait')

x <- plot.bamdata(ephy, breaksmethod='linear', color.interval=c(NA, 0.12), lwd=2)
addBAMMlegend(x, corners = c(0, 30, 200, 205), nTicks = 1, side = 3, axisOffset = 1, las = 1)

Description

Add Bamm-inferred rate shifts to a phylogeny plot

Usage

addBAMMshifts(ephy, index = 1, method = 'phylogram',
cex = 1, pch = 21, col = 1, bg = 2, msp = NULL,
shiftnodes = NULL, par.reset = TRUE)

Arguments

ephy an object of class bammdta.
method a character string indicating the method used in plotting. Must be "polar" or "phylogram".
index an integer indicating which posterior sample to use for adding shifts to the plotted tree.
cex a numeric indicating the character expansion ("size") of the plotted points.
pch an integer indicating the choice of plotting symbol.
addBAMMshifts

- **col**: an integer or character string indicating the border color of the plotting symbol.
- **bg**: an integer or character string indicating the background color of the plotting symbol.
- **msp**: if not NULL, an object of class phylo where each branch length is equal to the marginal probability of a shift occurring on that branch. Plotted points corresponding to shifts will be sized by these probabilities.
- **shiftnodes**: an optional vector of node numbers indicating the locations of shifts to plot.
- **par.reset**: a logical indicating whether to reset the graphical parameters before exiting.

Details

Any given sample from the posterior distribution sampled using BAMM contains a potentially unique configuration of rate shifts and associated parameters. There is no single "best" rate shift, but rather a set of shift configurations (and associated parameters) - along with their relative probabilities - sampled with MCMC. This function enables the user to plot the locations of shifts sampled with BAMM for a given sample from the posterior.

If the bammdata object contains just a single sample, these shifts will be plotted regardless of the value of index.

Note

If a shiftnodes argument is passed care should be taken to ensure that the nodes are in the same order as in the event data for the sample index.

Author(s)

Mike Grundler

See Also

getShiftNodesFromIndex, plot.bammdata

Examples

data(whales, events.whales)
ed <- getEventData(whales, events.whales, burnin=0.25)

#adding shifts to tree for specific posterior samples
plot(ed, method="polar")
addBAMMshifts(ed, index=5, "polar")

#multi-panel plotting and adding shifts
par(mfrow=c(2,3),mar=c(5,1,1,1))
samples = sample(1:length(ed$eventData), 6)
for (i in 1:6) {
  sed <- subsetEventData(ed, samples[i])
  plot(sed, par.reset=FALSE)
  addBAMMshifts(sed,index=1,method="phylogram",par.reset=FALSE)
}
assignColorBreaks  

Map macroevolutionary rates to colors

Description
Maps macroevolutionary rates to a set of NCOLORS.

Usage
assignColorBreaks(rates, NCOLORS = 64, spex = "s", logcolor = FALSE,
method = c("linear","quantile","jenks"), JenksSubset = NULL)

Arguments
rates  
a numeric vector of phenotypic rates or a list of numeric vectors of speciation
and extinction rates.

NCOLORS  
an integer number of colors to use for the mapping. Larger numbers do not
necessarily result in smoother looking color ramps. The default is 64 and is
probably sufficient for most purposes.

spex  
a character string. "s" means that speciation rates are used to make the map,
"e" means that extinction rates are used. Any other string, e.g. "se", means that
diversification rates are used. Ignored for BAMM trait data.

logcolor  
should the natural logarithm of rates be used for the color map.

method  
determines how the color breaks are created. See details.

JenksSubset  
Number of regularly spaced samples to subset from rates. Only relevant when
method = "jenks". See Details.

Details
If method = "quantile" macroevolutionary rates are binned into NCOLORS+1 percentiles and rates
in each bin are mapped to a color determined by the pal argument in plot.bammdata. Alternatively, if method = "linear" macroevolutionary rates are binned into NCOLORS+1 equal length
intervals between the minimum and maximum. If method = "jenks", macroevolutionary rates
are binned into NCOLORS+1 categories, according to the Jenks natural breaks classification method.
This method is borrowed from the field of cartography, and seeks to minimize the variance within
categories, while maximizing the variance between categories.

The Jenks natural breaks method was ported to C from code found in the classInt R package.

Value
A numeric vector of rate percentiles/intervals.

Author(s)
Mike Grundler, Pascal Title
See Also

plot.bammdata

Examples

data(whales, events.whales)
ed <- getEventData(whales, events.whales, 0.2)

ed <- dtRates(ed, 0.01)
colors <- assignColorBreaks(ed$dtrates$rates, spex="s") # speciation rates
# colors <- assignColorBreaks(ed$dtrates$rates[[1]])
# this also works for speciation rates

plot(ed, colorbreaks = colors, spex="s")
colors <- assignColorBreaks(ed$dtrates$rates, spex="se")
# diversification rates

# colors <- assignColorBreaks(ed$dtrates$rates[[1]] - ed$dtrates$rates[[2]])
# this also works for diversification rates

plot(ed, colorbreaks = colors, spex="se")
Details

This includes both the raw data and the BAMM output for three example analyses. The first is an analysis of speciation and extinction rates during the radiation of modern whales, using a time-calibrated tree from Steeman et al. (2009). The second is a BAMM analysis of phenotypic evolutionary rates (body mass) during the radiation of extant primates, taken from Vos and Mooers (2006) and Redding et al. (2010). The third is a BAMM analysis of speciation and extinction rates for a 300-species subset of ray-finned fishes, along with body size data for these species from Rabosky et al. (2013).

Dataset whales is the raw time-calibrated tree that was analyzed with BAMM, primates is the corresponding time-calibrated phylogeny of 233 primate species, and fishes is the time-calibrated phylogeny of 300 fish species. Log-transformed body masses for primates are in dataset mass.primates, and fish body sizes are in dataset traits.fishes.

The MCMC output files (mcmc.whales and mcmc.primates) are dataframes containing the raw MCMC output as generated by BAMM. Column headers in the dataframes includes the sampling generation, the current number of shifts in the simulation (N_shifts), the log-prior density of the parameters (logPrior), the log-likelihood of the data (logLik), the current parameter of the Poisson process governing the number of regime shifts (eventRate), and the MCMC acceptance rate (acceptRate). This is the file that would typically be analyzed as a first step towards assessing MCMC convergence (e.g., analyzing effective sample sizes of logLik and N_shifts).

The prior datasets (prior.primates and prior.whales) are the corresponding prior densities for the number of shifts generated by BAMM. These dataframes include only 3 columns: generation, N_shifts, and logPrior. Their utility lies in enabling the user to estimate Bayes factors for model comparison (see function computeBayesFactors).

The "core" BAMM output is included in the event data files (events.whales, events.primates and events.fishes). These are all the parameters sampled with MCMC that are relevant to reconstructing the nature and location of evolutionary rate dynamics across a phylogeny. Please refer to BAMM documentation for a detailed overview of this output, but a brief description is as follows:

generation: The index value of the state in the MCMC simulation (the "generation").

leftchild, rightchild: This defines a unique topological location where a rate shift was sampled. Specifically, for given right-left pair, the shift is sampled on the branch leading to the node from which rightchild and leftchild are descended (these two taxa are part of the spanning set of taxa for the node). If leftchild is "NA", this simply means that the shift was sampled on a terminal branch.

abstime: The absolute occurrence time of the shift, assuming that the time of the root node is 0.0.

lambdainit, lambdashift: for speciation extinction model, the initial speciation rate and rate change parameter for the process.

muinit: for speciation extinction model, the extinction rate (time-invariant)

betainit, betashift: for phenotypic evolutionary model, the initial (betainit) rate of phenotypic evolution and the rate change parameter (betashift).

References


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**BAMMtools-internal**  
*Internal BAMMtools functions*

**Description**

BAMMtools-internal functions are not routinely called by the user and are undocumented.

**Details**

Internal BAMMtools functions, either not intended to be called directly by the user or otherwise undocumented.

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**bayesFactorBranches**  
*Bayes factor evidence for rate shifts on individual branches*

**Description**

Computes Bayes factor evidence for a rate shift on every branch of a phylogenetic tree

**Usage**

`bayesFactorBranches(phy, priordata)`

**Arguments**

- `ephy` an object of class `bammdata`
- `priordata` an object of class `branchprior`
Details

This function returns a copy of a phylogenetic tree where each branch length is equal to the Bayes factor evidence in favor of a rate shift on a particular branch. Here, we imagine that there are two models: one with a rate shift on a given branch, and one without. Treating the "no shift" model as something akin to a null model, the Bayes factor can be computed as the ratio of posterior to prior odds of the model with a shift on a given branch, divided by the ratio of posterior to prior odds of the model without a shift.

By computing branch-specific marginal shift probabilities (using marginalShiftProbsTree), you can immediately extract the posterior probabilities of the relevant models. The branch length returned by this function is the posterior probability of a rate shift ($ prob_shift $), and the posterior probability of the model with no shift is simply $ 1 - prob_shift $.

Likewise, you can compute the prior odds in much the same way. The function getBranchShiftPriors computes the prior probability of a rate shift on each branch. As above, the prior probability of the no shift model is just $ 1 - prob_noshift $. The posterior-to-prior odds ratio for the shift model is $(posterior prob of shift) / (prior prob of shift)$. Simply multiplying this term by $(prior prob of no shift) / (posterior prob of no shift)$ gives us the Bayes factor.

In general, Bayes factors greater than 10 imply evidence in support of a rate shift, and Bayes factors greater than 100 imply very strong evidence for a shift on a particular branch.

Value

A object of class phylo but where each branch length is equal to the Bayes factor evidence in favor of a rate shift on a particular branch.

Author(s)

Dan Rabosky

See Also

getBranchShiftPriors, distinctShiftConfigurations, credibleShiftSet

Examples

data(whales, events.whales, prior.whales)
ed <- getEventData(whales, events.whales, burnin=0.1)
pdata <- getBranchShiftPriors(whales, prior.whales)
bftree <- bayesFactorBranches(ed, pdata)
margprobs <- marginalShiftProbsTree(ed)
plot.new()
par(mfcol=c(1,2))
# Original tree:
plot.phyl(whales, show.tip.label=FALSE)
mtext(side=3, text="original tree", cex=1)

plot.phyl(margprobs, show.tip.label=FALSE)
mtext(side=3, text="Marginal probs", cex=1)

plot.phyl(bftree, show.tip.label=FALSE)
cohorts

Visualize macroevolutionary cohorts

Description

Plots the matrix of pairwise correlations in rate regimes between all tips in a phylogeny.

Usage

cohorts(x, ephy, col, pal, lwd = 1, ofs = 0, use.plot.bammdata = FALSE, useraster = FALSE, LARGE = 500,...)

Arguments

- **x**: a matrix of pairwise correlations generated by `getCohortMatrix`.
- **ephy**: an object of class `bammdata`.
- **col**: a vector of colors passed to the function `image`. These will be used to color the values in `x`. See documentation for `image`.
- **pal**: the palette to use if `use.plot.bammdata=TRUE`. See options documented in the help file for `plot.bammdata`.
- **lwd**: a numeric indicating the width of branches in the phylogeny.
- **ofs**: a numeric controlling the offset of the phylogeny from the matrix plot. Appropriate values will probably be in the interval [0,0.1].
- **use.plot.bammdata**: logical. should a phylorate plot be generated?
- **useraster**: a logical indicating whether the function `image` should plot the matrix as a raster.
- **LARGE**: an integer. If trees have more tips than `LARGE`, `useraster` will be coerced to `TRUE`.
- **...**: further arguments passed to `plot.bammdata` if `use.plot.bammdata=TRUE`

Details

The plotting function creates an image of the BAMB correlation matrix between tip lineages of the phylogeny. Each correlation is the posterior frequency with which a pair of lineages occurs in the same macroevolutionary rate regime. Correlations are mapped to a set of colors, with warmer colors corresponding to higher correlations than cooler colors. The set of colors is specified by the `col` argument and a legend is plotted to guide interpretation of the color-correlation map. Trees are plotted on the margins of the matrix image. The correlation between any two tips can be inferred by finding their intersection within the matrix image.

IMPORTANT: the legend DOES NOT apply to the phylorate plots shown in the margin if `use.plot.bammdata=TRUE`. 
computeBayesFactors

Author(s)

Mike Grundler

See Also

plot.bammadata, getCohortMatrix, image

Examples

library(BAMMtools)
data(whales, events.whales)
ed <- getEventData(whales, events.whales, 0.1)
x <- getCohortMatrix(ed)
cohorts(x, ed)
cohorts(x, ed, col=richColors(64))
cohorts(x, ed, ofs=0.05, col=richColors(64))
cohorts(x, ed, pal="temperature", col=richColors(64))
# gray scale
cohorts(x, ed, col=gray(seq(0.2,0.9,length.out=128)), use.plot.bammadata=FALSE)

describe(computeBayesFactors computeBayesFactors)

Description

Computes pairwise Bayes factors for a set of macroevolutionary models sampled using BAMM, using MCMC simulation output.

Usage

computeBayesFactors(postdata, priordata, burnin = 0.1, modelset = NULL, ...)

Arguments

postdata Filename for the MCMC output file from a BAMM run. Alternatively, a dataframe containing this information.
priordata Filename for the BAMM-generated output file containing a simulation of shifts under the prior. Alternatively, a dataframe containing this information.
burnin What fraction of samples to discard from postdata as burnin?
modelset Integer set of models for which you wish to compute Bayes factors. An integer value of k implies a model with k rate shifts.
... Additional arguments to computeBayesFactors
credibleShiftSet

Details

This function returns a matrix of pairwise Bayes factors, where the Bayes factor is the ratio of marginal likelihoods between two models $M_i$ and $M_j$. Numerator models are given as rows, and denominator models as columns. Row names and column names give the number of shifts in the corresponding model. Suppose you have an output matrix with row and column names 0:3 (0, 1, 2, 3). Model 0 is a model with just a single process (starting at the root), and no among-lineage rate heterogeneity.

If `computeBayesFactors` gives a matrix `mm`, and `mm[2, 1]` is 10.0, this implies Bayes factor evidence of 10 in favor of the 2nd row model (a model with 1 process; e.g., `rownames(mm)[2]` over the first column model (a model with a single process).

It can be very difficult to approximate either the posterior or prior probability of models that are very rarely sampled. Suppose you have a simulation of a prior distribution that samples the models (M0, M1, M2, M3). Now, suppose your posterior distribution samples the models (M4, M5, M6, M7). There is no overlap between these sets of models. In other words, models sampled during the simulation of the prior are so improbable that they were not sampled during simulation of the posterior. Hence, we can’t even estimate their posterior probabilities with any degree of accuracy. Likewise, the models sampled during simulation of the posterior are very unlikely under the prior, and we can’t estimate their prior probabilities with any degree of accuracy. The function `computeBayesFactors` will automatically check and make sure that it is only computing Bayes factors for models where a non-zero probability (posterior or prior) can be estimated.

This is likely to change in the future with more robust methods for estimating these quantities in the tails of the distributions. However, keep in mind that if your posterior is very far from your prior, such that these models don’t overlap, you actually have strong evidence in favor of rate shifts (if the mean of the posterior distribution is greater than the prior mean) - this implies that the models expected under the prior alone have effectively zero posterior probability.

Value

A matrix of pairwise Bayes factors between models.

Author(s)

Dan Rabosky

Examples

```r
data(mcmc.whales)
data(prior.whales)
computeBayesFactors(mcmc.whales, prior.whales, burnin=0.1)
```

| credibleShiftSet | Credible set of macroevolutionary rate shift configurations from BAMM results |
Description

Computes the 95% (or any other %) credible set of macroevolutionary rate shift configurations from a bamdata object. These results can be analyzed further and/or plotted.

Usage

credibleShiftSet(ephy, prior, BFcriterion = 5, set.limit = 0.95, ...)

Arguments

- **ephy**: an object of class bamdata
- **prior**: An object of class branchprior. See `getBranchShiftPriors`
- **BFcriterion**: The Bayes factor criterion for including nodes as core shifts in the enumeration of distinct shift configurations.
- **set.limit**: the desired limit to the credible set. A value of 0.95 will return the 95% credible set of shift configurations.
- **...**: Other arguments to `credibleShiftSet`

Details

Computes the 95% credible set (or XX% credible set, depending on `set.limit`) of diversification shift configurations sampled using BAMB. This is analogous to a credible set of phylogenetic tree topologies from a Bayesian phylogenetic analysis.

To understand how this calculation is performed, one must first distinguish between "core" and "non-core" rate shifts. A "core shift" is a rate shift with a marginal probability that is substantially elevated above the probability expected on the basis of the prior alone. With BAMB, every branch in a phylogenetic tree is associated with some non-zero prior probability of a rate shift. Typically this is a very low per-branch shift probability (this prior is determined by the value of the "poisson-RatePrior" parameter in a BAMB analysis).

If we compute distinct shift configurations with every sampled shift (including those shifts with very low marginal probabilities), the number of distinct shift configurations will be overwhelmingly high. However, most of these configurations include shifts with marginal probabilities that are expected even under the prior alone. Hence, using these shifts to identify distinct shift configurations simply generates noise and isn’t particularly useful.

The solution adopted in BAMBtools is, for each branch in the phylogeny, to compute both the posterior and prior probabilities of a rate shift occurring. The ratio of these probabilities is a branch-specific Bayes factor: it is the posterior probability of a rate shift normalized by the corresponding prior probability. Hence, any branch with a Bayes factor value of 1.0 is one where the observed (posterior) odds of a rate shift are no different from the prior odds. A value of 10 implies that the posterior probability is 10 times the prior probability.

The user of `credibleShiftSet` must specify a `BFcriterion` argument. This is simply a Bayes factor cutoff value for identifying "important" shifts for the purposes of identifying distinct shift configurations. See the online documentation on this topic available at [www.bammp-project.org](http://www.bammp-project.org) for more information. If you specify `BFcriterion = 5` as an argument to `credibleShiftSet`, the function will ignore all shifts with Bayes factors less than 5 during the enumeration of topologically distinct shift configurations. Only shifts with a Bayes factor value greater than or equal to
Bayes criterion will be treated as core shifts for the purposes of identifying distinct shift configurations.

For each shift configuration in the credible set, this function will compute the average diversification parameters. For example, the most frequent shift configuration (the maximum a posteriori shift configuration) might have 3 shifts, and 150 samples from your posterior (within the bammdata object) might show this shift configuration. However, the parameters associated with each of these shift configurations (the actual evolutionary rate parameters) might be different for every sample. This function returns the mean set of rate parameters for each shift configuration, averaging over all samples from the posterior that can be assigned to a particular shift configuration.

See the examples below for a worked example.

**Value**

A class credibleShiftSet object with many components. Most components are an ordered list of length L, where L is the number of distinct shift configurations in the credible set. The first list element in each case corresponds to the shift configuration with the maximum a posteriori probability.

- **frequency**: A vector of frequencies of shift configurations, including those that account for set.limit (typically, 0.95 or 0.99) of the probability of the data. The index of the i'th element of this vector is the i'th most probable shift configuration (excepting ties).
- **shiftnodes**: A list of the "core" rate shifts (marginal probability > threshold) that occurred in each distinct shift configuration in the credible set. The i'th vector from this list gives the core shift nodes for the i'th shift configuration. They are sorted by frequency, so $x[shiftnodes[[1]]$ gives the shift nodes that occurred together in the shift configuration with the highest posterior probability.
- **indices**: A list of vectors containing the indices of samples in the bammdata object that are assigned to a given shift configuration. All are sorted by frequency.
- **cumulative**: Like frequency, but contains the cumulative frequencies.
- **BFcriterion**: The Bayes factor criterion used during enumeration of distinct shift configurations.
- **number.distinct**: Number of distinct shift configurations in the credible set.
- **set.limit**: Which credible set is this (0.9, 0.95, etc)?
- **coreshifts**: A vector of node numbers corresponding to the core shifts. All of these nodes have a Bayes factor of at least BFcriterion supporting a rate shift.

In addition, a number of components that are defined similarly in class phylo or class bammdata objects:

- **edge**: See documentation for class phylo in package ape.
- **Nnode**: See documentation for class phylo in package ape.
- **tip.label**: See documentation for class phylo in package ape.
- **edge.length**: See documentation for class phylo in package ape.
- **begin**: The beginning time of each branch in absolute time (the root is set to time zero).
credibleShiftSet

end

numberEvents

The ending time of each branch in absolute time.

numberEvents

An integer vector with the number of core events contained in the bammdata object for each shift configuration in the credible set. The length of this vector is equal to the number of distinct shift configurations in the credible set.

eventData

A list of dataframes. Each element holds the average rate and location parameters for all samples from the posterior that were assigned to a particular distinct shift configuration. Each row in a dataframe holds the data for a single event. Data associated with an event are: node - a node number. This identifies the branch where the event originates. time - this is the absolute time on that branch where the event originates (with the root at time 0). lam1 - an initial rate of speciation or trait evolution. lam2 - a decay/growth parameter. mu1 - an initial rate of extinction. mu2 - a decay/growth parameter. index - a unique integer associated with the event. See 'Details' in the documentation for getEventData for more information.

eventVectors

A list of integer vectors. Each element is for a single shift configuration in the posterior. For each branch in the bammdata object, gives the index of the event governing the (tipwards) end of the branch. Branches are ordered increasing here and elsewhere.

eventBranchSegs

A list of matrices. Each element of the list is a single distinct shift configuration. Each matrix has four columns: Column 1 identifies a node in phy. Column 2 identifies the beginning time of the branch or segment of the branch that subtends the node in Column 1. Column 3 identifies the ending time of the branch or segment of the branch that subtends the node in Column 1. Column 4 identifies the index of the event that occurs along the branch or segment of the branch that subtends the node in Column 1.

tipStates

A list of integer vectors. Each element is a single distinct shift configuration. For each tip the index of the event that occurs along the branch subtending the tip. Tips are ordered increasing here and elsewhere.

tipLambda

A list of numeric vectors. Each element is a single distinct shift configuration. For each tip is the average rate of speciation or trait evolution at the end of the terminal branch subtending that tip (averaged over all samples that are assignable to this particular distinct shift configuration).

tipMu

A list of numeric vectors. Each element is a single distinct shift configuration. For each tip the rate of extinction at the end of the terminal branch subtending that tip. Meaningless if working with BAMM trait results.

type

A character string. Either "diversification" or "trait" depending on your BAMM analysis.

downseq

An integer vector holding the nodes of phy. The order corresponds to the order in which nodes are visited by a pre-order tree traversal.

lastvisit

An integer vector giving the index of the last node visited by the node in the corresponding position in downseq. downseq and lastvisit can be used to quickly retrieve the descendants of any node. e.g. the descendants of node 89 can be found by downseq[which(downseq==89):which(downseq==lastvisit[89])].
Author(s)

Dan Rabosky

References

bamm-project.org

See Also

distinctShiftConfigurations, plot.bammshifts, summary.credibleshiftset, plot.credibleshiftset, getBranchShiftPriors

Examples

data(events.whales)
data(whales)
data(prior.whales)
ed <- getEventData(whales, events.whales)

# Here we get the prior distribution on branch-specific shifts:
priordist <- getBranchShiftPriors(whales, prior.whales)

cset <- credibleShiftSet(ed, prior = priordist, BFcriterion = 5)

# Here is the total number of samples in the posterior:
length(ed$eventData)

# And here is the number of distinct shift configurations:
cset$number.distinct

# Here is the summary statistics:
summary(cset)

# Accessing the raw frequency vector for the credible set:
cset$frequency

# The cumulative frequencies:
cset$cumulative

# The first element is the shift configuration with the maximum a posteriori probability. We can identify all the samples from
# posterior that show this shift configuration:
cset$indices[[1]]

# Now we can plot the credible set:
plot.credibleshiftset(cset, plotmax=4)
distinctShiftConfigurations

Identify distinct rate shift configurations

Description

Identify topologically distinct rate shift configurations that were sampled with BAMM, and assign each sample in the posterior to one of the distinct shift configurations.

Usage

distinctShiftConfigurations(phy, prior, BFcriterion, ...)

Arguments

ephy an object of class bammda
prior an object of class branchprior
BFcriterion Numeric value for the Bayes factor threshold used to identify branches with elevated shift probabilities relative to prior
... Other arguments to distinctShiftConfigurations (possibly deprecated args)

Value

an object of class bammshifts. This is a list with the following components

marg.probs A list of the marginal probability of a shift occurring at each node of the phylogeny for each distinct rate configuration.
bayesfactors Bayes factor evidence for a rate shift on each branch
shifts A list of the set of shift nodes for each distinct rate configuration.
samplesets A list of sample indices that reduce to each of the unique shift sets.
frequency A vector of frequencies of each distinct shift configuration.
coreshifts A vector of node numbers corresponding to the core shifts. All of these nodes have a Bayes factor of at least BFcriterion supporting a rate shift.
BFcriterion A single numeric value giving the Bayes factor threshold used during enumeration of distinct shift configurations

Results are sorted by frequency: $frequency[1]$ gives the most common shift configuration sampled. $shifts[[1]]$ gives the corresponding node indices for that configuration. $samplesets[[1]]$ gives the indices of samples with this configuration.

Author(s)

Dan Rabosky
dtRates

Calculate macroevolutionary rate changes on a phylogeny from BAMM output

See Also

plot.bammshifts, credibleShiftSet

Examples

data(whales, events.whales, prior.whales)

# Get the prior distribution on the number of shifts per branch:
bp <- getBranchShiftPriors(whales, prior.whales)

ed <- getEventData(whales, events.whales, burnin=0.25)
sc <- distinctShiftConfigurations(ed, bp, 10)
plot.bammshifts(sc, ed, rank=1)

dtRates(ephy, tau, ism = NULL, tmat = FALSE)

Arguments

ephys an object of class bammdata.
taus a numeric that specifies the size (as a fraction of tree height) of the segments that each branch will be discretized into.
ismas an integer vector indexing which posterior samples to include in the calculation.
tmatas a logical. If TRUE the matrix of branch segments is returned.

Details

dtRates bins the phylogeny into windows of time and calculates average rates of speciation/extinction or phenotypic evolution along each segment of a branch within a window. The width of each window is determined by tau. tau is a fraction of the root to tip distance so a value of tau = 0.01 bins the phylogeny into 100 time windows of equal width.
getBestShiftConfiguration

Value

A bammda object with a new component named "dtrates", which is a list with two or three components:

- **tau**: the parameter value of tau used in the calculation.
- **rates**: if ephy$type = "trait": a numeric vector with the phenotypic rates of each segment on each branch. if ephy$type = "diversification": a list with two components. The first component is a numeric vector of speciation rates. The second component is a numeric vector of extinction rates.
- **tmat**: a matrix of the starting and ending times of the segments on each branch. Only if tmat = TRUE.

Note

If there are zero length branches in the input tree NAs will result.

Author(s)

Mike Grundler

References

bamm-project.org

See Also

plot.bammda

Examples

data(whales, events.whales)
ed <- getEventData(whales, events.whales, burnin=0.25)

# use all posterior samples
ed <- dtRates(ed, tau=0.01)

# use specified range of posterior samples
ed <- dtRates(ed, tau=0.01, ism=50:150)

getBestShiftConfiguration

Get the best (sampled) rate shift configuration from a BAMM analysis

Description

Get the rate shift configuration with the maximum a posteriori probability, e.g., the shift configuration that was sampled most frequently with BAMM.
getBestShiftConfiguration

Usage

getBestShiftConfiguration(x, prior, BFcriterion = 5)

Arguments

x either a bammda object or a credibleshiftset object
prior An object of class branchprior. See getBranchShiftPriors
BFcriterion The Bayes factor criterion for including nodes as core shifts in the enumeration
of distinct shift configurations.

Details

This function estimates the rate shift configuration with the highest maximum a posteriori (MAP)
probability. It returns a bammda object with a single sample. This can be plotted with plot.bammda,
and individual rate shifts can then be added with addBAMMshifts.

The parameters of this object are averaged over all samples in the posterior that were assignable
to the MAP shift configuration. All non-core shifts have been excluded, such that the only shift
information contained in the object is from the "significant" rate shifts, as determined by the relevant
Bayes factor criterion.

You can extract the same information from the credible set of shift configurations. See credibleShift-
Set for more information.

Value

A class bammda object with a single sample, corresponding to the diversification rate shift config-
uration with the maximum a posteriori probability. See getEventData for details.

Author(s)

Dan Rabosky

See Also

gEVENTData, credibleShiftSet, plot.credibleshiftset, plot.bammda

Examples

data(whales, events.whales)
ed <- getEventData(whales, events.whales, burnin=0.1)

# Get prior distribution on shifts-per-branch:
data(prior.whales)
bp <- getBranchShiftPriors(whales, prior.whales)

# Pass the event data object in to the function:
best <- getBestShiftConfiguration(ed, bp, BFcriterion = 5)
plot.bammda(best, lwd=2)
addBAMMshifts(best, cex=2)
getBranchShiftPriors

# Now we can also work with the credible shift set:
css <- credibleShiftSet(ed, bp, BFcriterion = 5)

summary(css)

# examine model-averaged shifts from MAP configuration-
# This gives us parameters, times, and associated nodes
# of each evolutionary rate regime
# (note that one of them corresponds to the root)
css$eventData[[1]];

# Get bammdata representation of MAP configuration:
best <- getBestShiftConfiguration(css, bp, BFcriterion = 5);

plot.bammdata(best)
addBAMMshifts(best)

getBranchShiftPriors

Compute prior odds of a rate shift on each branch of a phylogeny from
BAMM output

Description

Computes the prior probability of a rate shift event for each branch. These results are important for identifying topological rate shift locations on phylogenies with marginal probabilities that exceed those predicted under the prior alone.

Usage

getBranchShiftPriors(phy, priordata)

Arguments

phy an object of class phylo
priordata Filename for the BAMM-generated output file containing a simulation of shifts under the prior. Alternatively, a dataframe containing this information.

Details

This function computes the prior odds on the distribution of numbers of rate shift events per branch under the prior. It returns an object of class 'branchprior', which is nothing more than a copy of the original phylogenetic tree but where each branch length has been replaced by the prior probability of a rate shift on each branch.

The significance of this function is that it lets us explicitly determine which branches have shift probabilities that are elevated relative to the prior expectation. The user does not work with the
output of this function directly; it is passed to other functions `credibleShiftSet` and `distinctShiftConfigurations`.

Note: If you are working with a subset of a bammdata object (created with `subtreeBAMM`), then you must generate a new branchpriors object with a pruned phylogeny that matches the one associated with your subsetted bammdata object.

**Value**

A class `branchprior` with all the components of the original class phylo object, with the following changes:

- `edge.length` branch lengths now represent the prior probability of a rate shift on each branch

**Author(s)**

Dan Rabosky

**References**

bamm-project.org

**See Also**

`distinctShiftConfigurations, plot.bammshifts, summary.credibleshiftset, plot.credibleshiftset, credibleShiftSet`

**Examples**

data(events.whales)
data(whales)
data(prior.whales)
ed <- getEventData(whales, events.whales)

# Get branch-specific cutoffs for identifying branches with # elevated shift probabilities:
bprior <- getBranchShiftPriors(whales, prior.whales)
cset <- credibleShiftSet(ed, bprior)

# Here is the total number of samples in the posterior:
length(ed$eventData)

# And here is the number of distinct shift configurations:
cset$number.distinct

# here is the summary statistics:
summary(cset)

# Accessing the raw frequency vector for the credible set:
cset$frequency

#The cumulative frequencies:
getCladeRates

getCumulative

# The first element is the shift configuration with the maximum
# a posteriori probability. We can identify all the samples from
# posterior that show this shift configuration:

cset$indices[[1]]

cset$indices

---

**getCladeRates**

*Compute clade-specific mean rates*

**Description**

Computes marginal clade-specific rates of speciation, extinction, or (if relevant) trait evolution from
**BAMM** output.

**Usage**

```
getCladeRates(eph, node = NULL, nodetype = "include", verbose = FALSE)
```

**Arguments**

- **eph**
  - an object of class *bamdata*
- **node**
  - If computing rates for a specific portion of tree, the node subtending the relevant subtree
- **nodetype**
  - Either "include" or "exclude". If nodetype = "include", the rates returned by the function will be for the subtree defined by node. If nodetype = "exclude", will compute mean rates for the tree after excluding the subtree defined by node.
- **verbose**
  - If TRUE, will print the sample index as mean rates are computed for each sample from posterior. Potentially useful for extremely large trees.

**Details**

Computes the time-weighted mean evolutionary rate for a given clade. Conversely, one can compute the rate for a given phylogeny while excluding a clade; this operation will give the "background" rate. It is important to understand several aspects of these mean rates. First, rates in the **BAMM** framework are not constant through time. Hence, the function computes the mean time-integrated rates across the subtree. Operationally, this is done by integrating the speciation rate with respect to time along each branch in the subtree. These time-integrated rates are then summed, and the sum is divided by the total sum of branch lengths for the subtree.

The function computes a rate for each sample in the posterior, and returns a list of rate vectors. Each rate in the corresponding vector is a mean rate for a particular sample from the posterior. Hence, you can think of the return value for this function as an estimate of the marginal distribution of rates for the focal clade. You can compute means, medians, quantiles, etc from these vectors.
getCohortMatrix

Value

A list with the following components:

- **lambda**: A vector of speciation rates (if applicable), with the i’th rate corresponding to the mean rate from the i’th sample in the posterior.
- **mu**: A vector of extinction rates (if applicable), with the i’th rate corresponding to the mean rate from the i’th sample in the posterior.
- **beta**: A vector of phenotypic rates (if applicable), with the i’th rate corresponding to the mean rate from the i’th sample in the posterior.

Author(s)

Dan Rabosky

References

bamm-project.org

Examples

data(events.whales)
data(whales)
ed <- getEventData(whales, events.whales)
all_rates <- getCladeRates(ed)

mean(all_rates$lambda)
mean(all_rates$mu)
# joint density of mean speciation and extinction rates:
plot(all_rates$mu ~ all_rates$lambda)

# clade specific rates: here for Dolphin subtree:
dol_rates <- getCladeRates(ed, node=140)
mean(dol_rates$lambda)
mean(dol_rates$mu)

getCohortMatrix  Compute the pairwise correlation in rate regimes between all tips in a bammdata object

Description

Takes a bammdata object and computes the pairwise correlation in evolutionary rate regimes between all tips in the phylogeny. This can be used to identify cohorts of taxa that share common macroevolutionary rate parameters. It can also be used to construct a correlation matrix for GLS analyses using BAMP-estimated tip rates of speciation, extinction, or phenotypic evolution.
Usage

getCohortMatrix(ephy)

Arguments

ephy an object of class bammdata

Details

The cohort matrix is important for interpreting and visualizing macroevolutionary dynamics. Each entry \([i, j]\) of the cohort matrix is the probability that taxon \(i\) and taxon \(j\) share a common macroevolutionary rate regime. To compute this, we simply tabulate the percentage of samples from the posterior where taxon \(i\) and taxon \(j\) were placed in the same rate regime. If there is no rate heterogeneity in the dataset (e.g., the data are best explained by a single rate regime), then all species will tend to share the same rate regime and all values of the cohort matrix will approach 1.

A value of 0 between any two taxa means that at least one rate shift occurred on the nodal path connecting them in 100% of samples from the posterior. A value of 0.50 would imply that 50% of samples from the posterior included a rate shift on the path connecting taxa \(i\) and \(j\). See below (examples) for an illustration of this.

Value

A numeric matrix of dimension \(k \times k\), where \(k\) is the number of species in the phylogeny included in the bammdata object. Species names are included as row names and column names. The matrix is symmetric, such that the values for entry \([i, j]\) will mirror those for \([j, i]\).

Author(s)

Dan Rabosky

References

www.bamm-project.org

Examples

data(whales)
data(events.whales)
ed <- getEventData(whales, events.whales)
cormat <- getCohortMatrix(ed)
dim(cormat)
hist(cormat, breaks=50)
# getEventData

Create bammdata object from MCMC output

## Description

getEventData reads shift configuration data (the "event data" output) from a BAMM analysis and creates a bammdata object. The bammdata object is fundamental for extracting information about macroevolutionary rate variation through time and among lineages.

## Usage

```r
getEventData(phy, eventdata, burnin = 0, nsamples = NULL, verbose = FALSE, type = "diversification")
```

## Arguments

- **phy**
  - An object of class phylo - specifically, the time calibrated tree that was analyzed with BAMM.

- **eventdata**
  - A character string specifying the path to a BAMM event-data file. Alternatively, an object of class data.frame that includes the event data from a BAMM run.

- **burnin**
  - A numeric indicating the fraction of posterior samples to discard as burn-in.

- **nsamples**
  - An integer indicating the number of posterior samples to include in the bammdata object. May be NULL.

- **verbose**
  - A logical. If TRUE progress is outputted to the console. Defaults to FALSE.

- **type**
  - A character string. Either "diversification" or "trait" depending on your BAMM analysis.

## Details

In the BAMM framework, an "event" defines a macroevolutionary process of diversification or trait evolution. Every sample from the posterior includes at least one process, defined by such an "event". If a given sample includes just a single event, then the dynamics of diversification or trait evolution can be described entirely by a single time-constant or time-varying process that begins at the root of the tree. Any sample from the posterior distribution may include a complex mixture of distinct processes. To represent temporal heterogeneity in macroevolutionary rates, BAMM models a rate $R$, e.g. speciation, as a function that changes exponentially with time: $R(t) = R(0) \times \exp(b \times t)$. Here $R(0)$ is the initial rate and $b$ is a parameter determining how quickly that rate grows or decays with time.

The eventdata file (or data frame) is a record of events and associated parameters that were sampled with BAMM during simulation of the posterior with reversible jump MCMC. This complex, information-rich file is processed into a bammdata object, which serves as the core data object for numerous downstream analyses. From a bammdata object, you can summarize rate variation through time, among clades, extract locations of rate shifts, summarize clade-specific rates of speciation and extinction, and more.
In general, the user does not need to be concerned with the details of a `bammdata` object. The object is used as input by a number of `BAMMtools` functions.

The parameter `nsamples` can be used to reduce the total amount of data included in the raw event-data output from a `BAMM` run. The final `bammdata` object will consist of all data for `nsamples` from the posterior. These `nsamples` are equally spaced after discarding some burnin fraction as "burn-in". If `nsamples` is set to `NULL`, the `bammdata` object will include all samples in the posterior after discarding the burnin fraction.

**Value**

A list with many components:

- **edge**
  - See documentation for class `phylo` in package `ape`.

- **Node**
  - See documentation for class `phylo` in package `ape`.

- **tip.label**
  - See documentation for class `phylo` in package `ape`.

- **edge.length**
  - See documentation for class `phylo` in package `ape`.

- **begin**
  - The beginning time of each branch in absolute time (the root is set to time zero)

- **end**
  - The ending time of each branch in absolute time.

- **numberEvents**
  - An integer vector with the number of events contained in `phy` for each posterior sample. The length of this vector is equal to the number of posterior samples in the `bammdata` object.

- **eventData**
  - A list of dataframes. Each element is a single posterior sample. Each row in a dataframe holds the data for a single event. Data associated with an event are:
    - **node** - a node number. This identifies the branch where the event originates.
    - **time** - this is the absolute time on that branch where the event originates (with the root at time 0).
    - **lam1** - an initial rate of speciation or trait evolution.
    - **lamR** - a decay/growth parameter.
    - **mu1** - an initial rate of extinction.
    - **muR** - a decay/growth parameter.
    - **index** - a unique integer associated with the event. See 'Details'.

- **eventVectors**
  - A list of integer vectors. Each element is a single posterior sample. For each branch in `phy` the index of the event that occurs along that branch. Branches are ordered increasing here and elsewhere.

- **eventBranchSegs**
  - A list of matrices. Each element is a single posterior sample. Each matrix has four columns:
    - **Column 1** identifies a node in `phy`.
    - **Column 2** identifies the beginning time of the branch or segment of the branch that subtends the node in `Column 1`.
    - **Column 3** identifies the ending time of the branch or segment of the branch that subtends the node in `Column 1`.
    - **Column 4** identifies the index of the event that occurs along the branch or segment of the branch that subtends the node in `Column 1`.

- **tipStates**
  - A list of integer vectors. Each element is a single posterior sample. For each tip the index of the event that occurs along the branch subtending the tip. Tips are ordered increasing here and elsewhere.

- **tipLambda**
  - A list of numeric vectors. Each element is a single posterior sample. For each tip the rate of speciation or trait evolution at the end of the terminal branch subtending that tip.
getEventData

tipMu  A list of numeric vectors. Each element is a single posterior sample. For each tip the rate of extinction at the end of the terminal branch subtending that tip. Meaningless if working with BAMM trait results.

meanTipLambda  For each tip the mean of the marginal posterior density of the rate of speciation or trait evolution at the end of the terminal branch subtending that tip.

meanTipMu  For each tip the mean of the marginal posterior density of the rate of extinction at the end of the terminal branch subtending that tip. Meaningless if working with BAMM trait results.

type  A character string. Either "diversification" or "trait" depending on your BAMM analysis.

downseq  An integer vector holding the nodes of phy. The order corresponds to the order in which nodes are visited by a pre-order tree traversal.

lastvisit  An integer vector giving the index of the last node visited by the node in the corresponding position in downseq. downseq and lastvisit can be used to quickly retrieve the descendants of any node. e.g. the descendants of node 89 can be found by downseq[which(downseq==89):which(downseq==lastvisit[89])].

Note

Currently the function does not check for duplicate tip labels in phy, which may cause the function to choke.

Author(s)

Dan Rabosky, Mike Grundler

References

bamm-project.org


See Also

summary.bammdata, plot.bammdata, dtRates.

Examples

data(primates)
data(events.primates)
xx <- getEventData(primates, events.primates, burnin=0.25, type = 'trait')

# compute mean phenotypic rate for primate body size evolution:
brates <- getCladeRates(xx)
mean(brates$beta)
getJensBreaks

# Plot rates:
plot.bammdata(xx)

---

getJensBreaks  Jenks natural breaks classification

Description

Given a vector of numeric values and the number of desired categories, calculate the optimum breakpoints using Jenks natural breaks optimization.

Usage

getJensBreaks(var, k, subset = NULL)

Arguments

- **var**: numeric vector
- **k**: number of groupings
- **subset**: Number of regularly spaced samples to subset from var. Intended to improve runtime for large datasets. If NULL, all values are used.

Details

getJensBreaks is called by assignColorBreaks.

The values in var are binned into k categories, according to the Jenks natural breaks classification method. This method is borrowed from the field of cartography, and seeks to minimize the variance within categories, while maximizing the variance between categories. If subset = NULL, all values of var are used for the optimization, however this can be a slow process with very large datasets. If subset is set to some number, then subset regularly spaced values of var will be sampled. This is slightly less accurate than when using the entirety of var but is unlikely to make much of a difference. If subset is defined but length(var) < subset, then subset has no effect.

The Jenks natural breaks method was ported to C from code found in the classInt R package.

Value

A numeric vector of intervals.

Author(s)

Pascal Title

See Also

See assignColorBreaks and plot.bammdata.
getMarginalBranchRateMatrix

Examples

# load whales dataset
data(whales, events.whales)
ed <- getEventData(whales, events.whales, burnin = 0.25)

# for demonstration purposes, we will extract the vector of speciation rates
ed <- dtRates(ed, tau = 0.01)
vec <- ed$dtrates$rates[[1]]

# Return breaks for the binning of speciation rates into 64 groups
getJenksBreaks(vec, 64)

---

getMarginalBranchRateMatrix

compute mean branch rates for bamndata object

Description

For each sample in the posterior, computes the mean rate for each branch in the focal phylogeny (speciation, extinction, trait evolution). If the bamndata object contains nsamples samples and the target phylogeny has nbranches branches, the function will compute a matrix of nbranches x nsamples.

Usage

getMarginalBranchRateMatrix(ephy, verbose = FALSE)

Arguments

ephy an object of class bamndata
verbose print progress during processing of bamndata object

Details

If a type = 'diversification' bamndata object is passed as an argument, the function will return matrices for both speciation and extinction. If type = 'trait' object, the matrix will simply be the corresponding phenotypic rates. Branch-specific rates are the mean rates computed by integrating the relevant rate-through-time function along each branch, then dividing by the length of the branch.

Value

Returns a list with the following components:

lambda_branch_matrix
A nbranches x nsamples matrix of mean speciation rates for each branch.
getMeanBranchLengthTree

mu_branch_matrix
   A nbranches x nsamples matrix of mean extinction rates for each branch.

beta_branch_matrix
   A nbranches x nsamples matrix of mean phenotypic rates for each branch.

Author(s)
   Dan Rabosky

Examples
   data(whales)
   data(events.whales)
   ed <- getEventData(whales, events.whales, nsamples = 10)
   mbr <- getMarginalBranchRateMatrix(ed)
   dim(mbr$lambda_branch_matrix)

getMeanBranchLengthTree

   Compute phylogeny with branch lengths equal to corresponding
   macroevolutionary rate estimates

Description
   Takes a bammdata object and computes a phylogenetic tree where branch lengths are equal to the
   mean of the marginal distributions of rates on each branch. This tree can be plotted to visualize rate
   variation across a phylogeny.

Usage
   getMeanBranchLengthTree(ephy, rate = "speciation")

Arguments
   ephy          an object of class bammdata
   rate          the type of rate-tree to be computed. Options: "speciation" (default), "extinc-
                   tion", "ndr" (net diversification), and "trait"

Value
   A list with the following components:

   phy           A phylogenetic tree, topologically identical to the model tree, but with branch
                  lengths replaced by the mean (marginal) rates on each branch as estimated from
                  the posterior samples in the bammdata object.
   mean          The mean rate over all branches
   median        the median rate over all branches
getmrcac

Find most recent common ancestors

description
Calculates the most recent common ancestor for each pair of tips. Used internally by getEventData

usage
getmrca(phy, t1, t2)

arguments

phy an object of class phylo.
t1 a vector of mode integer or character corresponding to tips in phy.
t2 a vector of mode integer or character corresponding to tips in phy.

details
Finds the most recent common ancestor for each pair of tips where pairs are defined as (t1[1], t2[1]), (t1[2], t2[2]), ..., (t1[i], t2[i]), ..., (t1[n], t2[n]).

value
A vector of node numbers of the common ancestor for each pair of tips.

author(s)
Mike Grundler
getRateThroughTimeMatrix

Generate rate-through-time matrix from bammdata object

Description
Computes a matrix of macroevolutionary rates at specified timepoints from a bammdata object. These rates can be used for plotting speciation rates (and other rates) through time.

Usage
getRateThroughTimeMatrix(ephy, start.time = NULL, end.time = NULL, nslices = 100, node = NULL, nodetype = "include")

Arguments
- ephy: an object of class bammdata
- start.time: the start time (in units before present) for the time sequence over which rates should be computed. If NULL, starts at the root
- end.time: the end time (in units before present) for the time sequence over which rates should be computed. If NULL, ends in the present
- nslices: The number of time points at which to compute rate estimates (between start.time and end.time)
- node: Allows user to extract rate-through-time information for the subtree descended from a specific node. Alternatively, a specified subtree can be excluded from the rate matrix calculations.
- nodetype: Two options: "include" and "exclude". If "include", computes rate matrix only for the descendants of subtree defined by node. If "exclude", computes rate matrix for all background lineages in tree after excluding the subtree defined by node. Ignored if node = NULL.

Details
Computes evolutionary rates for each sample in the posterior included as part of the bammdata object. Rates are computed by draping an imaginary grid over the phylogeny, where the grid begins at start.time and ends at end.time, with nslices vertical lines through the phylogeny. The mean rate at each point in time (for a given sample from the posterior) is simply the mean rate at that time for all branches that are intersected by the grid (see the grid plot in the examples section).

This function is used by plotRateThroughTime, but the user can work directly with the bammp-ratematrix object for greater control in plotting rate-through-time trajectories for individual clades. See examples for an example of how this can be used to plot confidence intervals on a rate trajectory using shaded polygons.

The node options are particularly useful. If you have run BAMM on a large phylogeny, you can easily generate the rate-through-time data for a particular subtree by specifying the node number along with nodetype = "include". Likewise, if you want to look at just the background rate - excluding some particular lineage - just specify nodetype = "exclude".
Value

An object of class `bammMratematrix` with the following components:

- `lambda` A `nsamples` x `nslices` matrix of speciation rates, where `nsamples` is the number of posterior samples in the `bammdata` object.
- `mu` A `nsamples` x `nslices` matrix of extinction rates
- `beta` A `nsamples` x `nslices` matrix of phenotypic rates (if applicable)
- `times` A vector of timepoints where rates were computed
- `times` A vector of timepoints where rates were computed (see example)
- `type` Either "diversification" or "trait", depending on the input data.

Author(s)

Dan Rabosky

See Also

- `plotRateThroughTime`

Examples

```r
## NOT RUN ##
# Plot a rate-through-time curve with confidence intervals for the whale dataset:

# data(whales, events.whales)
# ed <- getEventData(whales, events.whales)

# rmat <- getRateThroughTimeMatrix(ed)

# plot.new()
# plot.window(xlim=c(0, 36), ylim=c(0,.7))

## Speciation quantiles: plot 90% CIs
# qq <- apply(rmat$lambda, 2, quantile, c(0.05, 0.5, 0.95))

# xv <- c(rmat$times, rev(rmat$times))
# yv <- c(qq[1,], rev(qq[3,]))

## Add the confidence polygon on rate distributions:
# polygon(xv, yv, col='gray80', border=FALSE)

## Add the median rate line:
# lines(rmat$times, qq[2,], lwd=3, col='red')

## Add axes
# axis(1, at=seq(-5, 35, by=5))
# axis(2, at=seq(-0.2, 1, by=0.2), las=1)

#### Now we will show the actual grid used for rate calculations:
```
getShiftNodesFromIndex

Identify nodes associated with rate shifts from bammdata object

Description
Find the node numbers associated with rate shifts for a specified sample from the posterior distribution contained in a bammdata object.

Usage
getShiftNodesFromIndex(phy, index)

Arguments
- **phy**: a bammdata object
- **index**: The index value of the posterior sample from which you want to identify shift nodes. This is not the same as the actual generation number of the MCMC sample. If your bammdata object contains 100 samples from the posterior distribution, the value of index must range from 1 to 100.

Value
A vector of nodes (excluding the root) that define branches on which shifts occurred for the specified sample from the posterior. Will return a numeric of length 0 if no non-root shifts occur in the specified sample.

Author(s)
Dan Rabosky
getTipRates

Compute tip-specific macroevolutionary rates from bammdata object

Description

Return speciation, extinction, net diversification, or Brownian motion trait rates for all species in the phylogeny from BAMM output.

Usage

getTipRates(phy, returnNetDiv = FALSE, statistic = 'mean')

Arguments

- **phy**: an object of class bammdata.
- **returnNetDiv**: logical. If TRUE, then net diversification rates are returned, if FALSE, then both speciation and extinction rates are returned. If phy is of type trait, then this is ignored.
- **statistic**: logical: determines how the average tip rates should be calculated. Can be either mean or median.

Value

Returns a list with the following elements: If phy type is 'diversification':

- **lambda**: A matrix of tip speciation rates with species as rows, and posterior samples as columns.
- **mu**: A matrix of tip extinction rates with species as rows, and posterior samples as columns.

See Also

addBAMMshifts, plot.bammdata, maximumShiftCredibility

Examples

data(whales, events.whales)
ed <- getEventData(whales, events.whales)

# Get the maximum shift credibility configuration:
msc <- maximumShiftCredibility(ed)

# Get the nodes at which shifts occurred in the maximum shift credibility configuration:
getShiftNodesFromIndex(ed, index=msc$sampleindex)
A vector of average tip speciation rates, averaged with mean or median, depending on selected option for statistic. The vector is named with species names.

mu.avg

A vector of average tip extinction rates, averaged with mean or median, depending on selected option for statistic. The vector is named with species names.

If ephy type is 'diversification' and returnNetDiv = TRUE:

netdiv

A matrix of tip net diversification rates with species as rows, and posterior samples as columns.

netdiv.avg

A vector of average tip net diversification rates, averaged with mean or median, depending on selected option for statistic. The vector is named with species names.

If ephy type is 'trait':

beta

A matrix of tip phenotypic rates with species as rows, and posterior samples as columns.

beta.avg

A vector of average tip phenotypic rates, averaged with mean or median, depending on selected option for statistic. The vector is named with species names.

Author(s)
Pascal Title

See Also
Requires an object of class bammdata as obtained with getEventData.

Examples

data(whales, events.whales)
ephy <- getEventData(whales, events.whales, burnin=0.25)

#return a vector of average species-specific speciation rates.
meanlam <- getTipRates(ephy, returnNetDiv = FALSE, statistic = 'mean')$lambda.avg
meanlam

#return a vector of median species-specific net diversification rates.
ndr <- getTipRates(ephy, returnNetDiv = TRUE, statistic = 'median')$netdiv.avg

#Return mean species-specific speciation rates from all posterior
# samples in the \code{bammdata} object.
lam <- getTipRates(ephy, returnNetDiv = FALSE, statistic = 'mean')$lambda
rowMeans(lam)
**maximumShiftCredibility**

*Estimate maximum shift credibility configuration*

**Description**

This is one estimate of the "best" rate shift configuration, considering only those shift configurations that were actually sampled using BAMBAM's reversible jump MCMC simulator. This is analogous to the "maximum clade credibility tree" from a Bayesian phylogenetic analysis. It is not necessarily the same as the shift configuration with the maximum a posteriori probability.

**Usage**

`maximumShiftCredibility(ephy, maximize = "product")`

**Arguments**

- **ephy**: an object of class `BAMMdata`
- **maximize**: Maximize the marginal probability of the product or sum of branch-specific shifts

**Details**

This is one point estimate of the overall "best" rate shift configuration. Following an MCMC simulation, the marginal shift probabilities on each individual branch are computed using `marginalShiftProbsTree`. The shift configuration that maximizes the product (or sum, if specified) of these marginal branch-specific shift probabilities is the `maximum shift credibility configuration`.

This option is only recommended if you have no clear "winner" in your credible set of shift configurations (see `credibleShiftSet`). If you have a number of largely-equiprobable shift configurations in your 95% credible set, you may wish to try this function as an alternative for identifying a single best shift configuration. Otherwise, it is recommended that you present the shift configuration with the maximum a posteriori probability (see `getBestShiftConfiguration`).

**Value**

A list with the following components:

- **bestconfigs**: A vector of the index values of MCMC samples with shift configurations equal to the maximum. Usually, more than one state sampled during the MCMC simulation will have an identical (maximized) marginal probability. All samples given in this vector will have an identical shift configuration.
- **scores**: The optimality score (product or sum of marginal shift probabilities) for all sampled shift configurations in the `BAMMdata` object.
- **optimalityType**: Whether the product or sum of marginal shift probabilities was used to compute the maximum shift credibility configuration.
- **sampleindex**: A representative sample that is equal to the maximum shift credibility configuration (e.g., this can be plotted with `addBAMMshifts`).
**plot.bammdata**

**Author(s)**

Dan Rabosky

**See Also**

`marginalShiftProbsTree`, `addBAMMshifts`, `cumulativeShiftProbsTree`, `credibleShiftSet`, `getBestShiftConfiguration`

**Examples**

```r
data(whales)
data(events.whales)
ed <- getEventData(whales, events.whales, burnin=0.25)
best_config <- maximumShiftCredibility(ed)
plot.bammdata(ed)
addBAMMshifts(ed, method='phylogram', index=best_config$sampleindex)
```

---

**plot.bammdata**  
*Plot BAMM-estimated macroevolutionary rates on a phylogeny*

**Description**

`plot.bammdata` plots a phylogenetic tree from a `bammdata` object and colors each branch by the estimated rate of speciation, extinction, or trait evolution. Rates are not assumed to be constant in time, and the function can plot continuously-varying rates along individual branches.

**Usage**

```r
## S3 method for class 'bammdata'
plot(x, tau = 0.01, method = "phylogram",
    xlim = NULL, ylim = NULL, vtheta = 5, rbf = 0.001, show = TRUE, labels = FALSE,
    legend = FALSE, spex="s", lwd = 1, cex = 1, pal = "RdYlBu",
    mask = integer(0), mask.color = gray(0.5), colorbreaks = NULL, logcolor = FALSE,
    breaksmethod = "linear", color.interval = NULL, JenksSubset = 20000,
    par.reset = FALSE, direction = "rightwards", ...)
```

**Arguments**

- **x**: an object of class `bammdata`.
- **tau**: a numeric indicating the grain size for the calculations. See documentation for dtRates.
- **method**: a character string indicating the method for plotting the phylogenetic tree. method = "phylogram" (default) plots the phylogenetic tree using rectangular coordinates. method = "polar" plots the phylogenetic tree using polar coordinates.
- **xlim**: a numeric vector of coordinates for the x-axis endpoints. Defaults to NULL, in which case they are calculated automatically. The x-axis corresponds to time when the phylogeny is plotted facing to the left or to the right. The time at the root equals zero.
ylim  a numeric vector of coordinates for the y-axis endpoints. Defaults to NULL, in which case they are calculated automatically. Tips are plotted at integer values beginning from zero and stepping by one when the phylogeny is plotted facing to the left or to the right.

vtheta  a numeric indicating the angular separation (in degrees) of the first and last terminal nodes. Ignored if method = "phylogram".

rbf  a numeric indicating the length of the root branch as a fraction of total tree height. Ignored if method = "phylogram".

show  a logical indicating whether or not to plot the tree. Defaults to TRUE.

labels  a logical indicating whether or not to plot the tip labels. Defaults to FALSE.

legend  a logical indicating whether or not to plot a legend for interpreting the mapping of evolutionary rates to colors. Defaults to FALSE.

spex  a character string indicating what type of macroevolutionary rates should be plotted. "s" (default) indicates speciation rates, "e" indicates extinction rates, and any other character, e.g. "se", indicates net diversification rates. Ignored if ephyDtype = "trait".

lwd  a numeric specifying the line width for branches.

cex  a numeric specifying the size of tip labels.

pal  a character string or vector of mode character that describes the color palette. See Details for explanation of options.

mask  an optional integer vector of node numbers specifying branches that will be masked with mask.color when plotted.

mask.color  the color for the mask.

colorbreaks  a numeric vector of percentiles delimiting the bins for mapping rates to colors. If NULL (default) bins are calculated from the rates that are passed with the bammdata object.

logcolor  should colors be plotted on a log scale.

breaks.method  method used for determining color breaks. See help file for assignColorBreaks.

color.interval  Min and max value for the mapping of rates. If NULL, then min and max are inferred from the data. NA can also be supplied for one of the two values. See details.

JenksSubset  If breaks.method = "jenks", the number of regularly spaced samples to subset from the full rates vector. Only relevant for large datasets. See help file for assignColorBreaks.

par.reset  a logical indicating whether or not to reset the graphical parameters when the function exits. Defaults to FALSE.

direction  a character string. Options are "rightwards", "leftwards", "upwards", and "downwards", which determine the orientation of the tips when the phylogeny plotted.

...  further arguments passed to par.
**Details**

To calculate rates, each branch of the phylogeny is discretized into a number of small segments, and the mean of the marginal posterior density of the rate of speciation/extinction or trait evolution is calculated for each such segment. Rates are mapped to colors such that cool colors represent slow rates and warm colors represent fast rates. When the tree is plotted each of these small segments is plotted so that changes in rates through time and shifts in rates are visible as gradients of color. The `spex` argument determines the type of rate that will be calculated. `spex = "s"` will plot speciation rates, `spex = "e"` will plot extinction rates, and `spex = "se"` will plot diversification rates (speciation - extinction). Note that if `x$type = "trait"` the `spex` argument is ignored and rates of phenotypic evolution are plotted instead. If `legend = TRUE` the function will plot a legend that contains the mapping of colors to numerical values.

A number of color palettes come built in with BAMMtools. Color-blind friendly options include

\[ \text{BrBG, PiYG, PRGn, PuOr, RdBu, RdYlBu, BuOr, BuOrRd, DkRdBu, BuDkOr, GnPu} \]

Some color-blind unfriendly options include

\[ \text{RdYlGn, Spectral, temperature, terrain} \]

For more information about these color palettes visit colorbrewer2.org and geography.uoregon.edu/datagraphics/color_scales.htm or use the help files of the R packages RColorBrewer and dichromat.

Additionally, any vector of valid named colors may also be used. The only restriction is that the length of this vector be greater than or equal to three (you can provide a single color, but in this case the entire tree will be assigned the same color). The colors should be ordered from cool to warm as the colors will be mapped from low rates to high rates in the order supplied (e.g. `pal=c("darkgreen","yellow2","red")). The option `pal = "temperature"` uses the `rich.colors` function written by Arni Magnusson for the R package gplots.

Internally `plot.bammdata` checks whether or not rates have been calculated by looking for a component named "dtrates" in the `bammdata` object. If rates have not been calculated `plot.bammdata` calls `dtRates` with `tau`. Specifying smaller values for `tau` will result in smoother-looking rate
changes on the tree. Note that smaller values of \( \tau \) require more computation. If the \texttt{colorbreaks} argument is \texttt{NULL} a map of rates to colors is also made by calling \texttt{assignColorBreaks} with \texttt{NCOLORS = 64}. A user supplied \texttt{colorbreaks} argument can be passed as well. This allows one to plot parts of a tree while preserving the map of rates to colors that was made using rates for the entire tree.

If \texttt{color.interval} is defined, then those \texttt{min} and \texttt{max} values override the automatic detection of \texttt{min} and \texttt{max}. This might be useful if some small number of lineages have very high or very low rates, such that the map of colors is being skewed towards these extremes, resulting in other rate variation being drowned out. If specified, the color ramp will be built between these two \texttt{color.interval} values, and the rates outside of the color interval range will be set to the highest and lowest color.

If \texttt{plotNbammdata} is called repeatedly with the same \texttt{bammdata} object, computation can be reduced by first calling \texttt{dtrates} in the global environment.

**Value**

Returns (invisibly) a list with three components.

- \texttt{coords} A matrix of plot coordinates. Rows correspond to branches. Columns 1-2 are starting (x,y) coordinates of each branch and columns 3-4 are ending (x,y) coordinates of each branch. If \texttt{method = "polar"} a fifth column gives the angle (in radians) of each branch.
- \texttt{colorbreaks} A vector of percentiles used to group macroevolutionary rates into color bins.
- \texttt{colordens} A matrix of the kernel density estimates (column 2) of evolutionary rates (column 1) and the color (column 3) corresponding to each rate value.

**Author(s)**

Mike Grundler, Pascal Title

**Source**

colorbrewer2.org, geography.uoregon.edu/datagraphics/color_scales.htm

**See Also**

dtRates, addBAMMshifts, assignColorBreaks, subtreeBAMM, colorRampPalette

**Examples**

```r
data(whales, events.whales)
ed <- getEventData(whales, events.whales, burnin=0.25)

# the first call to plot.bammdata. No calculations or assignments of rates have been made
plot(ed, lwd = 3, spex = "s") # internally calls dtRates and assignColorBreaks

# Compare the different color breaks methods
par(mfrow=c(1,3))
plot(ed, lwd = 3, spex = "s", breakmethod = "linear")
title(main="linear")
plot(ed, lwd = 3, spex = "s", breakmethod = "quantile")
```
title(main="quantile")
plot(ed, lwd = 3, spex = "s", breaksmethod = "jenks")
title(main="jenks")

## NOT RUN##
## now plot.bammdata no longer calls dtRates
# ed <- dtRates(ed, tau = 0.01)
# xx <- plot(ed, lwd = 3, spex = "s")
#
## you can plot subtrees while preserving the original
## rates to colors map by passing the colorbreaks object as an argument
# sed <- subtreeBAMM(ed, node = 103)
# plot(sed, lwd = 3, colorbreaks = xx$colorbreaks)
# sed <- subtreeBAMM(ed, node = 140)
# plot(sed, lwd = 3, colorbreaks = xx$colorbreaks)
## note how if we do not pass colorbreaks the map is
## no longer relative to the rest of the tree and the plot is quite
## distinct from the original
# plot(sed, lwd = 3)
#
## if you want to change the value of tau and the rates to colors map for the entire tree
# ed <- dtRates(ed, tau = 0.002)
# xx <- plot(ed, lwd = 3, spex = "s")
## now you can re-plot the subtrees using this finer tau partition
# sed <- subtreeBAMM(ed, node = 103)
# sed <- dtRates(ed, 0.002)
# plot(sed, lwd = 3, colorbreaks = xx$colorbreaks)
# sed <- subtreeBAMM(ed, node = 140)
# sed <- dtRates(ed, 0.002)
# plot(sed, lwd = 3, colorbreaks = xx$colorbreaks)
#
## multi-panel plotting and adding shifts of specific posterior samples
# par(mfrow=c(2,3),mar=c(5,1,1,1))
# samples <- sample(1:length(ed$eventData), 6)
# ed <- dtRates(ed, 0.005)
# xx <- plot(ed, show=FALSE) #individual plots will have a color map relative to the mean
# for (i in 1:6) {
# ed <- dtRates(ed, 0.005, samples[i])
# plot(ed, colorbreaks=xx$colorbreaks)
# addBAMMshifts(ed,index=samples[i],method="phylogram")
#
# }
# dev.off()
#
## color options
# ed <- dtRates(ed,0.01)
# plot(ed, pal="temperature",lwd=3)
# plot(ed, pal="terrain",lwd=3)
# plot(ed, pal=c("darkgreen","yellow2","red"),lwd=3)
# plot(ed,method="polar",pal="Spectral", lwd=3)
# plot(ed,method="polar",pal="RdYlBu", lwd=3)
##END##
Description

Plots a random distinct rate shift configuration sampled by BAMM on a phylogeny.

Usage

```r
## S3 method for class 'bammshifts'
plot(x, ephy, method="phylogram", pal="RdYlBu", rank=NULL, index=NULL, spex="s",
     legend=TRUE, add.freq.text=TRUE, logcolor=FALSE, breaksmethod="linear",
     color.interval=NULL, JenksSubset=20000, ...)
```

Arguments

- `x`: an object of class `bammshifts`.
- `ephy`: an object of class `bammdata`.
- `method`: a character string for which plotting method to use. "phylogram" uses rectangular coordinates. "polar" uses polar coordinates.
- `pal`: the color palette to use in `plot.bammdata`.
- `rank`: the rank of the core shift configuration to plot. For the default (NULL) a random configuration is chosen.
- `index`: the posterior sample to plot. For the default (NULL) a random sample is chosen.
- `spex`: a character string indicating what type of macroevolutionary rates should be plotted. "s" (default) indicates speciation rates, "e" indicates extinction rates, and any other character, e.g. "se", indicates net diversification rates. Ignored if `ephy$type = "trait"`.
- `legend`: a logical indicating whether to plot a legend.
- `add.freq.text`: a logical indicating whether the frequency of each sampled shift configuration should be added to each plot.
- `logcolor`: should colors be plotted on a log scale.
- `breaksmethod`: method used for determining color breaks. See help file for `assignColorBreaks`.
- `color.interval`: Min and max value for the mapping of rates. One of the two values can be `NA`. See details in `plot.bammdata` for further details.
- `JenksSubset`: If `breaksmethod = "jenks"`, the number of regularly spaced samples to subset from the full rates vector. Only relevant for large datasets. See help file for `assignColorBreaks`.
- `...`: other arguments to `plot.bammdata`. 
Details

A rate shift configuration is the set of nodes of the phylogeny where a shift occurs in the macroevolutionary rate dynamic of diversification or trait evolution. Each posterior sample is a potentially distinct rate shift configuration. Different configurations may imply different macroevolutionary scenarios. This function helps visualize the different distinct rate shift configurations sampled by BAMM.

A core shift configuration is defined by a set of nodes that have shift probabilities that are substantially elevated relative to what you expect under the prior alone. These core configurations are inferred in distinctShiftConfigurations. It is almost certain that more than one core shift configuration will be sampled by BAMM. Moreover, each core shift configuration may contain many subconfigurations. A subconfiguration contains the core shift node configuration and zero or more additional shift nodes that occur with low marginal probability.

Points are added to the branches subtending the nodes of each rate configuration. The size of the point is proportional to the marginal probability that a shift occurs on a specific branch. If the instantaneous rate at a shift’s origin represents an initial increase above the ancestral instantaneous rate the point is red. If the instantaneous rate at a shift’s origin represents an initial decrease below the ancestral instantaneous rate the point is blue.

Author(s)

Mike Grundler, Dan Rabosky

References

bamm-project.org

See Also

distinctShiftConfigurations, plot.bammdata

Examples

data(whales, events.whales, prior.whales)

ed <- getEventData(whales, events.whales, burnin=0.25)

# Here we get prior for identifying "significant" (core) rate shifts
priordist <- getBranchShiftPriors(whales, prior.whales)

sc <- distinctShiftConfigurations(ed, prior = priordist, BFcriterion = 5)

plot(sc, ed)
plot.credibleshiftset  Plot credible set of rate shift configurations from BAMM analysis

Description

Plots the credible set of rate shift configurations from a BAMM analysis on a phylogeny

Usage

## S3 method for class 'credibleshiftset'
plot(x, plotmax=9, method="phylogram", pal="RdYlBu", shiftColor="black", spex="s", add.freq.text=TRUE, use.plot.bammdata=TRUE, border=TRUE, legend=FALSE, send2pdf=FALSE, logcolor = FALSE, breaksmethod='linear',
color.interval=NULL, JenksSubset=20000, ...)

Arguments

x  an object of class credibleshiftset.

plotmax  an integer number of plots to display.

method  a coordinate method to use for plotting. Options are "phylogram" or "polar".

pal  a color palette to use with plot.bammdata.

shiftColor  color to use for shift points.

spex  a character string indicating what type of macroevolutionary rates should be plotted. "s" (default) indicates speciation rates, "e" indicates extinction rates, and any other character, e.g. "se", indicates net diversification rates. Ignored if ephy$type = "trait".

add.freq.text  a logical indicating whether to add the posterior frequency of each shift configuration to the plotting region.

use.plot.bammdata  a logical indicating whether to use plot.bammdata (TRUE) or plot.phylo (FALSE).

border  a logical indicating whether to frame the plotting region.

legend  a logical indicating whether to plot a legend.

send2pdf  a logical indicating whether to print the figure to a PDF file.

logcolor  a logical indicating whether the rates should be log-transformed.

breaksmethod  method used for determining color breaks. See help file for assignColorBreaks.

color.interval  Min and max value for the mapping of rates. One of the two values can be NA. See details in plot.bammdata for further details.

JenksSubset  If breaksmethod = "jenks", the number of regularly spaced samples to subset from the full rates vector. Only relevant for large datasets. See help file for assignColorBreaks.

...  further arguments to pass to plot.bammdata.
Details
This produces phylorate plots for the plotmax most-probable shift configurations sampled with BAMM. Shift configurations are plotted in a single graphics window. The posterior probability (frequency) of each rate shift configuration in the posterior is shown (omitted with argument add.freq.text = FALSE).

Points are added to the branches subtending the nodes of each rate configuration. The size of the point is proportional to the marginal probability that a shift occurs on a specific branch.

Author(s)
Mike Grundler

References
bamm-project.org

See Also
credibleShiftSet, distinctShiftConfigurations, plot.bammdata, plot.bammshifts

Examples
data(events.whales)
data(whales)
ed <- getEventData(whales, events.whales)

# Get branch prior on number of shifts:
data(prior.whales)
bp <- getBranchShiftPriors(whales, prior.whales)
cset <- credibleShiftSet(ed, bp)
plot(cset)

plotRateThroughTime  Plot rates through time

Description
Generates a plot of diversification or phenotypic rate through time with confidence intervals.

Usage
plotRateThroughTime(ephy, useMedian = TRUE,
intervals=seq(from = 0, to = 1, by = 0.01),
ratetype = 'auto', nBins = 100, smooth = FALSE, smoothParam = 0.20,
opacity = 0.01, intervalCol='blue', avgCol='red', start.time = NULL,
end.time = NULL, node = NULL, nodetype='include', plot = TRUE, cex.axis=1,
cex.lab=1.3, lwd=3, xline=3.5, yline=3.5, mar=c(6,6,1,1), xticks=NULL,
yticks=NULL, xlim='auto', ylim='auto', add=FALSE, axis.labels=TRUE)
Arguments

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ephy</td>
<td>object of class bammdata or bamm-ratematrix</td>
</tr>
<tr>
<td>useMedian</td>
<td>a logical: will plot median if TRUE, mean if FALSE</td>
</tr>
<tr>
<td>intervals</td>
<td>if NULL, no intervals will be plotted, otherwise a vector of quantiles must be supplied (these will define shaded polygons)</td>
</tr>
<tr>
<td>ratetype</td>
<td>if ‘auto’, defaults to speciation (for diversification) or beta (for traits). Can alternatively specify ‘netdiv’ or ‘extinction’.</td>
</tr>
<tr>
<td>nBins</td>
<td>number of time slices used to generate rates through time.</td>
</tr>
<tr>
<td>smooth</td>
<td>a logical: whether or not to apply loess smoothing.</td>
</tr>
<tr>
<td>smoothParam</td>
<td>loess smoothing parameter, ignored if smooth = FALSE.</td>
</tr>
<tr>
<td>opacity</td>
<td>opacity of color for interval polygons.</td>
</tr>
<tr>
<td>intervalCol</td>
<td>color for interval polygons.</td>
</tr>
<tr>
<td>avgCol</td>
<td>color for mean/median line (line will not be plotted if avgCol = NULL).</td>
</tr>
<tr>
<td>start.time</td>
<td>start time (in units before present). If NULL, starts at root.</td>
</tr>
<tr>
<td>end.time</td>
<td>end time (in units before present). If NULL, ends at present.</td>
</tr>
<tr>
<td>node</td>
<td>if supplied, the clade descended from this node will be used or ignored, depending on nodetype.</td>
</tr>
<tr>
<td>nodetype</td>
<td>if ‘include’, rates will be plotted only for the clade descended from node. If ‘exclude’, the clade descended from node will be left out of the calculation of rates.</td>
</tr>
<tr>
<td>plot</td>
<td>a logical: if TRUE, a plot will be returned, if FALSE, the data for the plot will be returned.</td>
</tr>
<tr>
<td>cex.axis</td>
<td>size of axis tick labels.</td>
</tr>
<tr>
<td>cex.lab</td>
<td>size of axis labels.</td>
</tr>
<tr>
<td>lwd</td>
<td>line width of the average rate.</td>
</tr>
<tr>
<td>xline</td>
<td>margin line for placing x-axis label.</td>
</tr>
<tr>
<td>yline</td>
<td>margin line for placing y-axis label.</td>
</tr>
<tr>
<td>mar</td>
<td>passed to par() to set plot margins.</td>
</tr>
<tr>
<td>xticks</td>
<td>number of ticks on the x-axis, automatically inferred if NULL.</td>
</tr>
<tr>
<td>yticks</td>
<td>number of ticks on the y-axis, automatically inferred if NULL.</td>
</tr>
<tr>
<td>xlim</td>
<td>vector of length 2 with min and max times for x axis. X axis is time since present, so if plotting till the present, xlim[2]=0. Can also be ‘auto’.</td>
</tr>
<tr>
<td>ylim</td>
<td>vector of length 2 with min and max rates for y axis. Can also be ‘auto’.</td>
</tr>
<tr>
<td>add</td>
<td>a logical: should rates be added to an existing plot.</td>
</tr>
<tr>
<td>axis.labels</td>
<td>a logical: if TRUE, axis labels will be plotted.</td>
</tr>
</tbody>
</table>
Details

If the input ephy object has been generated by `getEventData` and is of class `bammdata`, then `start.time`, `end.time`, `node` and `nodetype` can be specified. If the input ephy object has been generated by `getRateThroughTimeMatrix` and is of class `bamm-ratematrix`, then those arguments cannot be specified because they are needed to generate the rate matrix, which in this case has already happened.

The user has complete control of the plotting of the confidence intervals. Confidence intervals will not be plotted at all if `intervals=NULL`. If a single confidence interval polygon is desired, rather than overlapping polygons, then intervals can specify the confidence interval bounds, and opacity should be set to 1 (see examples).

If working with a large dataset, we recommend first creating a `bamm-ratematrix` object with `getRateThroughTimeMatrix` and then using that object as input for `plotRateThroughTime`. This way, the computation of rates has already happened and will not slow the plotting function down, making it easier to adjust plotting parameters.

Value

If `plot = FALSE`, then a list is returned with the following components:

- **poly**: a list of matrices, where each matrix contains the coordinates that define each overlapping confidence interval polygon.
- **avg**: a vector of y-coordinates for mean or median rates used to plot the average rates line.
- **times**: a vector of time values, used as x-coordinates in this plot function.

Author(s)

Pascal Title

See Also

See `getEventData` and `getRateThroughTimeMatrix` to generate input data.

Examples

```r
## NOT RUN
# data(events.whales)
# data(whales)
# ephy <- getEventData(whales,events.whales)

## Simple plot of rates through time with default settings
# plotRateThroughTime(eph)

## Plot two processes separately with 90% CI and loess smoothing
# plotRateThroughTime(eph, intervals=seq(from=0,0.9,by=0.01), smooth=TRUE,
# node=141, nodetype='exclude', ylim=c(0,1.2))
# plotRateThroughTime(eph, intervals=seq(from=0,0.9,by=0.01), smooth=TRUE,
# node=141, nodetype='include', add=TRUE, intervalCol='orange')
```
# legend('topleft', legend=c('Dolphins', 'Whales'), col='red',
# fill=c('orange', 'blue'), border=FALSE, lty=1, lwd=2, merge=TRUE, seg.len=0.6)
#
## Same plot, but from bamr-ratematrix objects
## rmat1 <- getRateThroughTimeMatrix(ephy, node=141, nodetype='exclude')
## rmat2 <- getRateThroughTimeMatrix(ephy, node=141, nodetype='include')
##
## plotRateThroughTime(rmat1, intervals=seq(from=0,0.9,by=0.01),
## smooth=TRUE, ylim=c(0,1.2))
##
## plotRateThroughTime(rmat2, intervals=seq(from=0,0.9,by=0.01),
## smooth=TRUE, add=TRUE, intervalCol='orange')
##
## To plot the mean rate without the confidence envelope
## plotRateThroughTime(ephy, useMedian=FALSE, intervals=NULL)
##
## To plot the mean rate, with a single 95% confidence envelope, grayscale
## plotRateThroughTime(ephy, useMedian=FALSE, intervals=c(0.05,0.95),
## intervalCol='gray70', avgCol='black', opacity=1)
##
## To not plot, but instead return the plotting data generated in this function,
## we can make plot=FALSE
## plotRateThroughTime(ephy, plot=FALSE)
##END##

---

**samplingProbs**

*Creates clade-specific sampling fractions*

### Description

If the user would like to specify species sampling on a clade-by-clade basis, a sampling probability table can be provided to BAMM.

### Usage

```r
samplingProbs(tree, cladeTable, cladeRichness = NULL,
               globalSampling, output, writeToDisk = TRUE)
```

### Arguments

- **tree**: an object of class `phylo`.
- **cladeTable**: a dataframe with one column of species names and a second column of group assignment.
- **cladeRichness**: either `NULL` or a vector of species counts, named by clade names.
- **globalSampling**: percent sampling for the backbone of the phylogeny
- **output**: path + output file name
- **writeToDisk**: a logical, should the table be written to disk, defaults to `TRUE`. 

samplingProbs

Details

This function handles two types of input: The cladeTable can either contain the species found in the phylogeny, along with clade assignment of those species, or it can contain more species than found in the phylogeny. If the table only contains those species in the phylogeny, then a vector cladeRichness must be provided that contains known clade richness. If the cladeTable contains more than the species in the phylogeny, then cladeRichness should be set to NULL. The globalSampling value should represent the overall completeness of species sampling in terms of major clades. See bamm-project.org for additional details.

Value

If writeToDisk = TRUE, then no object is returned. If writeToDisk = FALSE, then a dataframe is returned. The resultant table must contain one row for each species in the phylogeny, along with clade assignment, and sampling fraction. The first line must contain the overall sampling fraction for the phylogeny and must be written as tab-delimited, with no headers.

Author(s)

Pascal Title

Examples

# Generate dummy data
(t7:3,(t8:2,t9:2):1):1);")
tree$tip.label <- paste(rep('Species',9),1:9,sep='')
spTable <- as.data.frame(matrix(nrow=9,ncol=2))
spTable[,1] <- tree$tip.label
spTable[1:3,2] <- 'cladeA'
spTable[4:6,2] <- 'cladeB'
spTable[7:9,2] <- 'cladeC'
richnessVec <- c(cladeA=5, cladeB=4, cladeC=12)

# Option 1: We have a table of clade assignment for the species in the tree,
# along with a vector of known clade richness
spTable
richnessVec
samplingProbs(tree, cladeTable = spTable, cladeRichness = richnessVec,
globalSampling = 1, writeToDisk = FALSE)

# Option 2: We have a table of known species, beyond the sampling in the phylogeny
spTable <- rbind(spTable, c('Species10','cladeA'),c('Species11','cladeA'),
c('Species12','cladeC'), c('Species13','cladeC'),c('Species14','cladeC'))

spTable
samplingProbs(tree, cladeTable = spTable, cladeRichness = NULL,
globalSampling = 0.9, writeToDisk = FALSE)
Description

Set priors for BAMM analysis

Usage

```r
setBAMMpriors(phy, total.taxa = NULL, traits=NULL,
outfile = 'myPriors.txt', Nmax = 1000)
```

Arguments

- `phy`: an object of class `phylo`, e.g., the phylogenetic tree you will analyze with BAMM
- `total.taxa`: If doing speciation-extinction analysis, the total number of taxa in your clade. If your tree contains all taxa in the clade (100% sampling), then leave this as NULL
- `traits`: A filename where the trait data (BAMM format) are stored. Leave NULL if doing a speciation-extinction analysis.
- `outfile`: Filename for outputting the sample priors block. If NULL, then a dataframe is returned instead.
- `Nmax`: If analyzing a very large tree for phenotypic evolution, uses only this many taxa to estimate priors for your dataset. Avoid matrix inversion issues with large numbers of tips.

Details

This is a "quick and dirty" tool for identifying approximately acceptable priors for a BAMM analysis. We have found that choice of prior can have a substantial impact on BAMM analyses. It is difficult to simply set a default prior that applies across datasets, because users often have trees with branch lengths in very different units (e.g., numbers of substitutions versus millions of years). Hence, without some careful attention, you can inadvertently specify some very bad prior distributions. This function is designed to at least put you in the right ballpark for decent prior distributions, but there are no guarantees that these are most appropriate for your data.

The general rules applied here are:

For the `lambdaInitPrior`, we estimate the speciation rate of the data under a pure birth model. We then set this prior to give an exponential distribution with a mean five times greater than this computed pure birth speciation estimate.

The `lambdaShiftPrior` is the standard deviation of the normal prior on the exponential change parameter `k`. We set the prior distribution based on the age of the root of the tree. We set the standard deviation of this distribution such that 2 standard deviations give a parameter that will yield a 90% decline in the initial speciation rate between the root of the tree and the tips. The basic model is `lambda(t) = lambda_0 * exp(k * t)`. This is a straightforward calculation: let `x = -log(0.1) / TMAX`, where TMAX is the age of the tree. Then set the standard deviation equal to `(x / 2)`.
We set muInitPrior equal to lambdaInitPrior.

For trait evolution, we first compute the maximum likelihood estimate of the variance of a Brownian motion process of trait evolution. The prior betaInitPrior is then set to an exponential distribution with a mean 5 times greater than this value (similar to what is done for lambda and mu, above).

This function generates an output file containing a prior parameters block that can be pasted directly into the priors section of your BAMM control file.

**Value**

The function does not return anything. It simply performs some calculations and writes formatted output to a file.

**Author(s)**

Dan Rabosky

---

### ShiftProbsTree

**Branch-specific rate shift probabilities**

**Description**

marginalShiftProbsTree computes a version of a phylogenetic tree where each branch length is equal to the marginal probability that a shift occurred on a particular branch. The cumulativeShiftProbsTree includes the cumulative probability that a shift occurred on a given branch. See details.

**Usage**

```r
cumulativeShiftProbsTree(phy)
marginalShiftProbsTree(phy)
```

**Arguments**

- `ephy` : An object of class `bammdata`

**Details**

The marginal shift probability tree is a copy of the target phylogeny, but where each branch length is equal to the branch-specific marginal probability that a rate-shift occurred on the focal branch. For example, a branch length of 0.333 implies that 1/3 of all samples from the posterior had a rate shift on the focal branch.

**Note:** It is highly inaccurate to use marginal shift probabilities as a measure of whether diversification rate heterogeneity occurs within a given dataset. Consider the following example. Suppose you have a tree with topology (A, (B, C)). You find a marginal shift probability of 0.5 on the branch leading to clade C, and also a marginal shift probability of 0.5 on the branch leading to clade BC. Even though the marginal shift probabilities appear low, it may be the case that the joint probability of a shift occurring on either the branch leading to C or BC is 1.0. Hence, you could be extremely confident (posterior probabilities approaching 1.0) in rate heterogeneity, yet find that no
single branch has a particularly high marginal shift probability. In fact, this is exactly what we ex-
pect in most real datasets, because there is rarely enough signal to strongly support the occurrence
of a shift on any particular branch.

The cumulative shift probability tree is a copy of the target phylogeny but where branch lengths
are equal to the cumulative probability that a rate shift occurred somewhere on the path between
the root and the focal branch. A branch length equal to 0.0 implies that the branch in question has
evolutionary rate dynamics that are shared with the evolutionary process starting at the root of the
tree. A branch length of 1.0 implies that, with posterior probability 1.0, the rate dynamics on a
branch are decoupled from the "root process".

Value

An object of class phylo, but with branch lengths equal to the marginal or cumulative shift proba-
bilities.

Author(s)

Dan Rabosky

References

bamm-project.org

See Also

maximumShiftCredibility

Examples

data(whales)
data(events.whales)
ed <- getEventData(whales, events.whales)

# computing the marginal shift probs tree:
mst <- marginalShiftProbsTree(ed)

# The cumulative shift probs tree:
cst <- cumulativeShiftProbsTree(ed)

# compare the two types of shift trees side-by-side:
plot.new()
par(mfrow=c(1,2))
plot.phylo(mst, no.margin=TRUE, show.tip.label=FALSE)
plot.phylo(cst, no.margin=TRUE, show.tip.label=FALSE)
speciesByRatesMatrix  Compute species-specific rate through time trajectories

Description

Computes the mean of the marginal posterior density of speciation/extinction or phenotypic rates for equally spaced points along the root to tip path for each species

Usage

speciesByRatesMatrix(ephy, nslices, index, spex)

Arguments

ephy  an object of class bammdata

nslices  an integer number of time slices. This determines the number of equally spaced points in time at which rates are computed for each species

index  an integer or vector of mode integer indicating which posterior samples to use in the calculation. If NULL (default) all samples are used

spex  a character string. "s" (default) calculates speciation rates; "e" calculates extinction rates; "se" calculates diversification rates. Ignored if ephy$type = "trait"

Value

A list with two components:

times  A vector of time points where rates were calculated

rates  A species X times matrix of rate through time trajectories

Author(s)

Mike Grundler

References

bamm-project.org

See Also

generateRateThroughTimeMatrix
Examples

data(whales, events.whales)
ed <- getEventData(whales, events.whales, burnin=0.25)
ratemat <- speciesByRatesMatrix(ed, nslices = 100)

dolphins <- extract.clade(whales, 140)$tip.label
plot.new()
plot.window(xlim=c(0, 35), ylim=c(0, 0.8))
for (i in 1:nrow(ratemat$rates)) {
  if (whales$tip.label[i] %in% dolphins) {
    lines(ratemat$times, ratemat$rates[i, ], lwd=2, col=4)
  } else {
    lines(ratemat$times, ratemat$rates[i, ], lwd=2, col=8)
  }
}axis(1, seq(-5, 35, 5))
axis(2, seq(-0.2, 0.8, 0.2), las=1)
mtext("Time since root", 1, line=2.5)
mtext("Speciation rate", 2, line=2.5)

subsetEventdata

Subset a bammdata object

Description

Subsets a bammdata object. Returns a bammdata object after extracting a specified set of samples from the posterior.

Usage

subsetEventdata(phy, index)

Arguments

ephy an object of class bammdata
index A vector of integers corresponding to samples to be extracted from the posterior distribution of shift configurations included in the bammdata object.

Details

This will result in an error if you attempt to access samples that do not exist in the phy data object. For example, if your bammdata object includes 100 samples from a posterior distribution sampled with BAMM, you can only attempt to subset with index values 1:100.

Value

A bammdata object, but only containing index samples from the posterior in the original object.
Author(s)

Dan Rabosky

Examples

data(whales, events.whales)
ed <- getEventData(whales, events.whales)
ed2 <- subsetEventData(ed, index=1)
plot.bammda(ed2)
addBAMMshifts(ed2, cex=2)

subtreeBAMM

Pulls out a subtree from bammda object

Description

Given a set of tips or a node, this function extracts the corresponding subtree from the bammda object. User should specify either a set of tips or a node, and the node will overwrite the tips if both are given.

Usage

subtreeBAMM(ephy, tips=NULL, node=NULL)

Arguments

ephy an object of class bammda.
tips an integer or character vector indicating which tips (more than one) to be included in the subtree.
node an integer indicating the root of the subtree to be extracted, and it must correspond to an innernode on the tree.

Details

This function allows users to extract a subtree from a big bammda object, and examine the subset using plot.bammda

Author(s)

Huateng Huang

See Also

getmrca, plot.bammda
Examples

```r
data(whales, events.whales)
ephy <- getEventData(whales, events.whales, burnin=0.25)

# specify a set of tips for the subtree
tips <- sample(ephy$tip.label, size=20, replace=FALSE)
subphy <- subtreeBAMM(ephy, tips=tips)

# specify an inner node for subsetting
subphy <- subtreeBAMM(ephy, node=103)

# plot the subtree
plot(subphy)
```

summary.bamdata  
*Summary of rate shift results from BAMM analysis.*

Description

Summarizes the posterior distribution on the number of shifts.

Usage

```r
## S3 method for class 'bamdata'
summary(object, display = 10, print=T, ...)
```

Arguments

- `object` an object of class `bamdata`.
- `display` an integer for the number of rows of the posterior to display.
- `print` Print summary of shift distribution in console window?
- `...` additional arguments (unused).

Details

Prints to console the number of posterior samples and the posterior distribution on the number of shifts, which is just the fraction of samples in the posterior having 0, 1, 2,...,n shifts.

Value

Returns (invisibly) a dataframe with 2 components:

- `shifts` the number of shifts
- `prob` the corresponding posterior probability of a model with a given number of rate shifts.
Author(s)

Mike Grundler, Dan Rabosky

References

bamm-project.org

Examples

data(whales, events.whales)
ephy <- getEventData(whales, events.whales, nsamples=100)
summary(ephy)

summary.branchprior  Summary of class "branchprior" object.

Description

Prints summary attributes of the branchprior object

Usage

## S3 method for class 'branchprior'
summary(object, ...)
## S3 method for class 'branchprior'
print(x, ...)

Arguments

object, x  an object of class branchprior.
...
  additional arguments (unused).

Author(s)

Dan Rabosky

References

bamm-project.org

See Also

distinctShiftConfigurations, plot.bammshifts, credibleShiftSetgetBranchShiftPriors
**summary.credibleshiftset**

*Summary of credible set of shift configurations from a BAMM analysis.*

**Description**

Prints summary attributes of the BAMM credible set of shift configurations.

**Usage**

```r
# S3 method for class 'credibleshiftset'
summary(object, ...)
# S3 method for class 'credibleshiftset'
print(x, ...)
```

**Arguments**

- `object`, `x` an object of class `credibleshiftset`.
- `...` additional arguments (unused).

**Details**

Prints to console summary attributes of the XX% credible set of shift configurations sampled using BAMM. Attributes printed include: the number of distinct configurations in the XX% credible set and the posterior probability, cumulative probability, and number of rate shifts in the 9 most-probable shift configurations.

**Value**

`summary.credibleshiftset` returns (invisibly) a dataframe with a number of rows equal to the number of shift configurations in the credible set and four columns:

- **rank** The ranked index of each shift configuration (ranked by posterior probability)
- **probability** the posterior probability of each shift configuration
- **cumulative** the cumulative probability of each shift configuration
- **N_shifts** the number of rate shifts in each shift configuration (can be zero).

**Author(s)**

Dan Rabosky

**References**

- [bamm-project.org](http://bamm-project.org)

**See Also**

- `distinctShiftConfigurations`, `plot.bammshifts`, `credibleShiftSet`
**Examples**

```r
data(events.whales)
data(whales)
ed <- getEventData(whales, events.whales)

data(prior.whales)
bp <- getBranchShiftPriors(whales, prior.whales)
cset <- credibleShiftSet(ed, bp)
summary(cset)
```

**Description**

For each branch in a phylogenetic tree, evaluates the evidence (posterior probability or Bayes factor) that macroevolutionary rates have varied through time.

**Usage**

```r
testTimeVariableBranches(ephys, prior_tv = 0.5, return.type = "posterior")
```

**Arguments**

- `ephys` an object of class `bammdata`.
- `prior_tv` The prior probability that rate shifts lead to a new time-varying rate process (versus a time-constant process).
- `return.type` either "posterior" or "bayesfactor", depending on which form of evidence you would like.

**Details**

In Bamm 2.0, rate shifts on trees can lead to time-varying or constant-rate diversification processes. In other words, the model will incorporate temporal variation in rates only if there is sufficient evidence in the data to favor it. The function `testTimeVariableBranches` enables the user to extract the evidence in favor of time-varying rates on any branch of a phylogenetic tree from a bammdata object.

The function returns a copy of the original phylogenetic tree, but where branch lengths have been replaced by either the posterior probability (`return.type = "posterior"`) or the Bayes factor evidence (`return.type = "bayesfactor"`) that the macroevolutionary rate regime governing each branch is time-variable. Consider a particular branch X on a phylogenetic tree. If the length of this branch is 0.97 and `return.type = "posterior"`, this implies that branch X was governed by a time-varying rate dynamic in 97% of all samples in the posterior. Alternatively, only 3% of samples specified a constant rate dynamic on this branch.
The function also provides an alternative measure of support if return.type = "bayesfactor". In this case, the Bayes factor evidence for temporal rate variation is computed for each branch. We simply imagine that diversification rates on each branch can be explained by one of two models: either rates vary through time, or they do not. In the above example (branch X), the Bayes factor would be computed as follows, letting \( \text{Prob}_{\text{timevar}} \) and \( \text{Prior}_{\text{timevar}} \) be the posterior and prior probabilities that a particular branch is governed by a time-varying rate process:

\[
\frac{\text{Prob}_{\text{timevar}}}{1 - \text{Prob}_{\text{timevar}}} \cdot \frac{1 - \text{Prior}_{\text{timevar}}}{\text{Prior}_{\text{timevar}}}
\]

The Bayes factor is not particularly useful under uniform prior odds (e.g., \( \text{prior}_{\text{tv}} = 0.5 \)), since this simply reduces to the ratio of posterior probabilities. Note that the prior must correspond to whatever you used to analyze your data in BAMM. By default, time-variable and time-constant processes are assumed to have equal prior odds.

This function can be used several ways, but this function allows the user to quickly evaluate which portions of a phylogenetic tree have "significant" evidence for rate variation through time (see examples below).

Value

An object of class \text{phylo}, but where branch lengths are replaced with the desired evidence (posterior probability or Bayes factor) that each branch is governed by a time-varying rate dynamic.

Author(s)

Dan Rabosky

Examples

```r
# Load whale data:
data(whales)
data(events.whales)
ed <- getEventData(whales, events.whales, burnin=0.1, nsamples=200)

# compute the posterior probability of
time-varying rates on each branch
tree.pp <- testTimeVariableBranches(ed)

# Plot tree, but color all branches where the posterior
# probability of time-varying rates exceeds 95%:
colvec <- rep("black", nrow(whales$edge))
colvec[tree.pp$edge.length >= 0.95] <- 'red'
plot.phylo(whales, edge.color=colvec, cex=0.5)

# now, compute Bayes factors for each branch:
tree bf <- testTimeVariableBranches(ed, return.type = "bayesfactor")

# now, assume that our prior was heavily stacked in favor
# of a time-constant process:
tree bf2 <- testTimeVariableBranches(ed, prior_tv = 0.1, return.type = "bayesfactor")
```
# Plotting the branch-specific Bayes factors against each other:

plot.new()
par(mar=c(5,5,1,1))
plot.window(xlim=c(0, 260), ylim=c(0, 260))
points(tree.bf$edge.length, tree.bf$edge.length, pch=21, bg='red', cex=1.5)
axis(1)
axis(2, las=1)
mtext(side=1, text="Bayes factor: prior_tv = 0.1", line=3, cex=1.5)
mtext(side = 2, text = "Bayes factor: uniform prior odds", line=3, cex=1.5)

# and you can see that if your prior favors CONSTANT RATE dynamics
# you will obtain much stronger Bayes factor support for time varying rates
# IF the evidence is present in your data to support time variation.
# To be clear, the Bayes factors in this example were computed from the
# same posterior probabilities: it is only the prior odds that differed.

---

**traitDependentBAMM**  
*STRAPP: STructured Rate Permutations on Phylogenies*

**Description**

Given a bammdata object and a vector of trait data (continuous), assess whether the correlation between the trait and bamm estimated speciation rate is significant using permutation. A set of posterior samples is randomly drawn from the bammdata object. If the trait is continuous, this function calculates the correlation coefficients between the trait and tip speciation rates (observed correlation), as well as that with permuted speciation rates for each posterior sample. In a one-tailed test for positive correlations, the reported p-value is the proportion of the posterior samples in which the observed correlation is larger than the correlations calculated with permuted rates. In a two-tailed test, the reported p-value is the proportion of the posterior samples in which the null correlation is as extreme as the correlation observed. If the trait is binary, the U statistic of the Mann-Whitney test is calculated instead of correlation coefficients to assess whether there is a significant difference in speciation rate between the two trait states. For categorical traits with more than two states, the Kruskal-Wallis rank sum statistic is used.

**Usage**

```r
traitDependentBAMM(ephy, traits, reps, return.full = FALSE, method = 'spearman',
                   logrates = TRUE, two.tailed = TRUE, traitorder = NA, nthreads = 1)
```

**Arguments**

- `ephy`: an object of class bammdata.
- `traits`: a vector of trait data, with names corresponding to tips in the bammdata object. It can be numeric or categorical.
**traitDependentBAMM**

- **reps**
  - an integer specifying the number of permutations (i.e., the number of posterior samples to randomly draw with replacement from the bammdata object)

- **return.full**
  - a logical. If TRUE, the list of posterior samples, the observed correlation for each posterior sample, and the null distribution will be included in the returned object. Defaults to FALSE.

- **method**
  - a character string, must be one of 'spearman', 'pearson', "mann-whitney", or "kruskal". Defaults to 'spearman'. You can specify just the initial letter.

- **logrates**
  - a logical. If TRUE log-transform the rates before analysis. Defaults to TRUE. This can only matter for the pearson correlation.

- **two.tailed**
  - a logical, used for continuous trait data. If TRUE, perform a two-tailed statistical test (i.e., if the null distribution is symmetric, it is equivalent to doubling the p-value). Defaults to TRUE.

- **traitorder**
  - a character string specifying the direction of correlation for the alternative hypothesis. For continuous traits, it must be either "positive" or "negative"; only the initial letter is needed. For binary traits, it must be a string indicating states with increasing speciation rate under the alternative hypothesis, separated by comma (e.g., 'A, B'). One-tailed test for categorical data with more than two states is not supported.

- **nthreads**
  - number of threads to use for parallelization of the function. The R package snow must be loaded for nthreads > 1.

**Details**

Speciation rates are permuted in a way such that pairwise covariances in rates between species are maintained. That is, tips with the same tipstates still have the same rate of speciation after permutation. Posterior samples are randomly selected with replacement from the bammdata object, so reps could be smaller or larger than the total number of samples in the object.

**Value**

- **estimate**
  - a numeric value for continuous trait data- the average observed correlation between tip speciation rates and the trait across the posterior samples. For categorical traits, it is a list showing the median species-specific speciation rates for each trait state.

- **p.value**
  - a numeric value. The probability that the observed correlation is less than or equal to a sample from the null distribution.

- **method**
  - a character string, as input.

- **two.tailed**
  - a logical, as input.

- **gen**
  - an integer vector, recording which posterior samples were selected. Only present when return.full is TRUE.

- **obs.corr**
  - a numeric vector, the observed correlation coefficients for each posterior sample. Only present when return.full is TRUE. For binary traits, centered U statistics (U - n1* n2/2; where n1 and n2 are the number of species in each state of the binary trait) is reported

- **null**
  - a numeric vector. The null distribution of correlation coefficients (or centered U statistics for binary traits) from permutation. Only present when return.full is TRUE.
**writeEventData**

**Author(s)**
Daniel L. Rabosky, Huateng Huang

**References**

bamm-project.org


**See Also**

subtreeBAMM

**Examples**

```r
# using a small subset of the fish data set (300 taxa) in Rabosky et al. 2013. Nat. Com. paper
data(fishes)
data(events.fishes)
xx <- getEventData(phy = fishes, eventdata = events.fishes, type = "diversification")
#traits.fishes is the trait -- body size
data(traits.fishes)
x <- traitDependentBAMM(ephy = xx, traits = traits.fishes, reps = 1000, return.full = TRUE, method = 's', logrates = TRUE, two.tailed = TRUE)
```

**writeEventData**  Write a bammdata object to disk

**Description**

writeEventData takes a bammdata object and re-writes it back into a tree file and an event csv file.

**Usage**

```r
writeEventData(ephy, outtreefile, outeventfile)
```

**Arguments**

- **ephy** bammda object
- **outtreefile** the file name for outputting the tree
- **outeventfile** the file name for outputting the event csv file
Author(s)

Huateng Huang

See Also

subtreeBAMM
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