

Package ‘Quartet’

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Title Comparison of Phylogenetic Trees Using Quartet and Split Measures

Description Calculates the number of four-taxon subtrees consistent with a pair of cladograms, calculating the symmetric quartet distance of Bandelt & Dress (1986), Reconstructing the shape of a tree from observed dissimilarity data, *Advances in Applied Mathematics*, 7, 309-343 <[doi:10.1016/0196-8858\(86\)90038-2](https://doi.org/10.1016/0196-8858(86)90038-2)>, and using the tqDist algorithm of Sand et al. (2014), tqDist: a library for computing the quartet and triplet distances between binary or general trees, *Bioinformatics*, 30, 2079–2080 <[doi:10.1093/bioinformatics/btu157](https://doi.org/10.1093/bioinformatics/btu157)> for pairs of binary trees.

URL <https://ms609.github.io/Quartet/>,
<https://github.com/ms609/Quartet/>

BugReports <https://github.com/ms609/Quartet/issues/>

Copyright Incorporates code modified from tqDist
<[doi:10.1093/bioinformatics/btu157](https://doi.org/10.1093/bioinformatics/btu157)>.

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`AllQuartets`*List all quartets*

Description

Lists all choices of four taxa from a tree.

A more computationally efficient alternative to [combn](#).

Usage

```
AllQuartets(nTips)
```

```
## S3 method for class 'numeric'  
AllQuartets(nTips)
```

```
## S3 method for class 'phylo'  
AllQuartets(nTips)
```

Arguments

`nTips` Integer, specifying the number of tips in a tree; or a tree, whose tips will be counted.

Value

`AllQuartets()` returns a matrix with four rows and `choose(n_tips, 4)` columns, with each column corresponding to a unique selection of four different integers less than or equal to `nTips`.

Author(s)

[Martin R. Smith](#) (martin.smith@durham.ac.uk)

See Also

States of quartets in given trees: [QuartetStates\(\)](#)

Other quartet counting functions: [CompareQuartetsMulti\(\)](#), [CompareQuartets\(\)](#), [ResolvedQuartets\(\)](#)

Examples

```
AllQuartets(5)
```

```
combn(5, 4) # Provides the same information, but for large  
            # values of n_tips is significantly slower.
```

CompareQuartets	<i>Compare quartet states by explicit enumeration</i>
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Description

CompareQuartets() uses explicit enumeration to compare two lists of quartet states, detailing how many are identical and how many are unresolved. For most purposes, the faster function [QuartetStatus\(\)](#) will be preferable.

Usage

CompareQuartets(x, cf)

Arguments

x, cf List of quartet states, perhaps generated by [QuartetStates\(\)](#).

Value

Returns an array of seven numeric elements, corresponding

N The total number of quartet *statements* for two trees of n leaves, i.e. $2Q$.

Q The total number of quartets for n leaves.

s The number of quartets that are resolved identically in both trees.

d The number of quartets that are resolved differently in each tree.

r1 The number of quartets that are resolved in tree 1, but not in tree 2.

r2 The number of quartets that are resolved in tree 2, but not in tree 1.

u The number of quartets that are unresolved in both trees.

Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

References

Estabrook GF, McMorris FR, Meacham CA (1985). "Comparison of undirected phylogenetic trees based on subtrees of four evolutionary units." *Systematic Zoology*, **34**(2), 193–200. [doi:10.2307/2413326](https://doi.org/10.2307/2413326).

See Also

- [QuartetStatus\(\)](#) generates the same output from a list of trees.

Other element-by-element comparisons: [CompareQuartetsMulti\(\)](#), [CompareSplits\(\)](#), [PairSharedQuartetStatus\(\)](#), [QuartetState\(\)](#), [SharedQuartetStatus\(\)](#), [SplitStatus\(\)](#)

Other quartet counting functions: [AllQuartets\(\)](#), [CompareQuartetsMulti\(\)](#), [ResolvedQuartets\(\)](#)

Examples

```
trees <- list(TreeTools::BalancedTree(6),
             TreeTools::PectinateTree(6))
quartets <- QuartetStates(trees)
CompareQuartets(quartets[[1]], quartets[[2]])
```

CompareQuartetsMulti *Compare one tree's quartets against others'*

Description

CompareQuartetsMulti() counts how many quartets in one tree are resolved in the same way or different ways in a forest of comparison trees.

Usage

```
CompareQuartetsMulti(x, cf)
```

Arguments

x Object of class phylo representing the tree of interest.
cf Comparison tree of class phylo, or list thereof, each with the same leaves as x.

Details

CompareQuartetsMulti() explicitly evaluates each quartet in each tree. As such its runtime will increase hyper-exponentially with the number of leaves in trees being compared. 30 leaves will take around 5 seconds; 40 closer to 20 s, and 50 around a minute.

Value

CompareQuartetsMulti() returns a named integer vector specifying the number of quartets whose resolution in x matches all or any of the resolutions in cf.

Named elements are:

N The total number of quartet *statements* for the given number of n -leaf trees, i.e. $n_trees \times Q$.

Q The total number of quartets for n leaves.

s_all The number of quartets that are resolved identically in all trees.

s_any The number of quartets that are resolved in x, and identically in at least one of cf.

d_all The number of quartets that are resolved in every tree in cf, but never in the same way as they are resolved in x.

d_any The number of quartets in x that are resolved differently (i.e. contradicted) in at least one tree in cf.

r1_all The number of quartets that are resolved in x, but not in any of cf.

r1_any The number of quartets that are resolved in x, but unresolved in at least one of cf.

r2_all The number of quartets that are resolved in all of cf, but not in x.

r2_any The number of quartets that are resolved in at least one of cf, but not in x.

u_all The number of quartets that are unresolved in all trees.

u_any The number of quartets that are unresolved in x and at least one tree in cf.

x_only The number of quartets in x that are not resolved the same way in any of cf.

Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

See Also

Other element-by-element comparisons: [CompareQuartets\(\)](#), [CompareSplits\(\)](#), [PairSharedQuartetStatus\(\)](#), [QuartetState\(\)](#), [SharedQuartetStatus\(\)](#), [SplitStatus\(\)](#)

Other quartet counting functions: [AllQuartets\(\)](#), [CompareQuartets\(\)](#), [ResolvedQuartets\(\)](#)

Examples

```
library('TreeTools')
CompareQuartetsMulti(x = CollapseNode(as.phylo(42, 6), 8:9),
                    cf = list(BalancedTree(6), PectinateTree(6),
                              CollapseNode(as.phylo(1337, 6), 9:10)))
```

CompareSplits

Compare status of splits

Description

Reports whether splits are present or contradicted in a set of reference splits.

Usage

```
CompareSplits(splits, splits2)
```

```
CompareBipartitions(splits, splits2)
```

Arguments

splits An object that can be coerced into class `Splits` using [as.Splits](#).

splits2 Splits against which to compare splits.

Value

A named vector of eight integers, listing the number of unique splits that:

- **N** exist in total; i.e. the number of splits in `splits1` plus the number in `splits2`, equivalent to $2s + d1 + d2 + r1 + r2$;
- **P1** occur in `splits1`
- **P2** occur in `splits2`
- **s** occur in both `splits1` and `splits2`;
- **d1** occur in `splits1` but are contradicted by `splits2`;
- **d2** occur in `splits2` but are contradicted by `splits1`;
- **r1** occur in `splits1` only, being neither present in nor contradicted by `splits2`;
- **r2** occur in `splits2` only, being neither present in nor contradicted by `splits1`;
- **RF** occur in one tree only; i.e. $d1 + d2 + r1 + r2$, the Robinson-Foulds distance.

Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

References

- Estabrook GF, McMorris FR, Meacham CA (1985). “Comparison of undirected phylogenetic trees based on subtrees of four evolutionary units.” *Systematic Zoology*, **34**(2), 193–200. [doi:10.2307/2413326](https://doi.org/10.2307/2413326).
- Robinson DF, Foulds LR (1981). “Comparison of phylogenetic trees.” *Mathematical Biosciences*, **53**(1-2), 131–147. [doi:10.1016/00255564\(81\)900432](https://doi.org/10.1016/00255564(81)900432).

See Also

Equivalent function for quartets: [CompareQuartets\(\)](#)

Other element-by-element comparisons: [CompareQuartetsMulti\(\)](#), [CompareQuartets\(\)](#), [PairSharedQuartetStatus\(\)](#), [QuartetState\(\)](#), [SharedQuartetStatus\(\)](#), [SplitStatus\(\)](#)

Examples

```
splits1 <- TreeTools::BalancedTree(8)
splits2 <- TreeTools::PectinateTree(8)
```

```
CompareSplits(splits1, splits2)
```

Description

Wrappers for functions in 'tqDist', which calculate triplet and quartet distances between pairs of trees.

Usage

```
QuartetDistance(file1, file2)
QuartetAgreement(file1, file2)
PairsQuartetDistance(file1, file2)
OneToManyQuartetAgreement(file1, file2)
AllPairsQuartetDistance(file)
AllPairsQuartetAgreement(file)
TripletDistance(file1, file2)
PairsTripletDistance(file1, file2)
AllPairsTripletDistance(file)
```

Arguments

file, file1, file2
Paths to files containing a tree or trees in Newick format, possibly created using [TQFile\(\)](#).

Value

...Distance() functions return the distance between the requested trees.

...Agreement() functions return the number of triplets or quartets that are:

- A, resolved in the same fashion in both trees;
- E, unresolved in both trees.

Comparing a tree against itself yields the totals (A+B+C) and (D+E) referred to by Brodal *et al.* (2013) and Holt *et al.* (2014).

Functions

- `QuartetDistance`: Returns the quartet distance between the tree in `file1` and the tree in `file2`.
- `QuartetAgreement`: Returns a vector of length two, listing [1] the number of resolved quartets that agree (A); [2] the number of quartets that are unresolved in both trees (E). See Brodal et al. (2013).
- `PairsQuartetDistance`: Quartet distance between the tree on each line of `file1` and the tree on the corresponding line of `file2`.
- `OneToManyQuartetAgreement`: Quartet distance between the tree in `file1` and the tree on each line of `file2`.
- `AllPairsQuartetDistance`: Quartet distance between each tree listed in `file` and each other tree therein.
- `AllPairsQuartetAgreement`: Quartet status for each pair of trees in `file`.
- `TripletDistance`: Triplet distance between the single tree given in each file.
- `PairsTripletDistance`: Triplet distance between the tree on each line of `file1` and the tree on the corresponding line of `file2`.
- `AllPairsTripletDistance`: Triplet distance between each tree listed in `file` and each other tree therein.

Author(s)

- Algorithms: Brodal *et al.* (2013); Holt *et al.* (2014).
- C implementation: Sand *et al.* (2014); modified for portability by Martin R. Smith.
- R interface: Martin R. Smith.

References

- Brodal GS, Fagerberg R, Mailund T, Pedersen CNS, Sand A (2013). “Efficient algorithms for computing the triplet and quartet distance between trees of arbitrary degree.” *SODA '13 Proceedings of the Twenty-Fourth Annual ACM-SIAM Symposium on Discrete Algorithms*, 1814–1832. doi:10.1137/1.9781611973105.130.
- Holt MK, Johansen J, Brodal GS (2014). “On the scalability of computing triplet and quartet distances.” In *Proceedings of 16th Workshop on Algorithm Engineering and Experiments (ALENEX) Portland, Oregon, USA*.
- Sand A, Holt MK, Johansen J, Brodal GS, Mailund T, Pedersen CNS (2014). “tqDist: a library for computing the quartet and triplet distances between binary or general trees.” *Bioinformatics*, **30**(14), 2079–2080. ISSN 1460-2059, doi:10.1093/bioinformatics/btu157.

See Also

- `QuartetStatus()` takes trees, rather than files, as input.
- `TQFile()` creates a temporary file containing specified trees.

PlotQuartet

Plot quartet on tree topologies

Description

Draws a tree, highlighting the members of a specified quartet in colour.

Usage

```
PlotQuartet(tree, quartet, overwritePar = TRUE, caption = TRUE, ...)
```

Arguments

tree	A tree of class <code>phylo</code> , or a list of such trees. The first member of <code>tree</code> will be considered the 'reference' tree.
quartet	A vector of four integers, corresponding to numbered leaves on the tree; or a character vector specifying the labels of four leaves.
overwritePar	Logical specifying whether to use existing <code>mfrow</code> and <code>mar</code> parameters from <code>par()</code> (FALSE), or to plot trees side-by-side in a new graphical device (TRUE).
caption	Logical specifying whether to annotate each plot to specify whether the quartet selected is in the same or a different state to the reference tree.
...	Additional parameters to send to <code>plot()</code> .

Value

`PlotQuartet()` returns `invisible()`, having plotted a tree in which the first two members of quartet are highlighted in orange, and the second two highlighted in blue.

Author(s)

[Martin R. Smith \(martin.smith@durham.ac.uk\)](mailto:martin.smith@durham.ac.uk)

Examples

```
data("sq_trees")

oPar <- par(mfrow = c(3, 6), mar = rep(0.5, 4))
PlotQuartet(sq_trees, c(2, 5, 3, 8), overwritePar = FALSE)
par(oPar)
```

`QuartetPoints`*Plot tree differences on ternary plots*

Description

Generate points to depict tree difference (in terms of resolution and accuracy) on a ternary plot.

Usage

```
QuartetPoints(trees, cf = trees[[1]])
```

```
SplitPoints(trees, cf = trees[[1]])
```

```
BipartitionPoints(trees, cf = trees[[1]])
```

Arguments

<code>trees</code>	A list of trees of class <code>phylo</code> , with identically labelled tips.
<code>cf</code>	Comparison tree of class <code>phylo</code> . If unspecified, each tree is compared to the first tree in <code>trees</code> .

Details

The ternary plot will depict the number of quartets or splits that are:

- resolved in the reference tree (`cf`), but neither present nor contradicted in each comparison tree (`trees`);
- resolved differently in the reference and the comparison tree;
- resolved in the same manner in the reference and comparison trees.

If the reference tree (`cf`) is taken to represent the best possible knowledge of the 'true' topology, then polytomies in the reference tree represent uncertainty. If a tree in `trees` resolves relationships within this polytomy, it is not possible to establish (based only on the reference tree) whether this resolution is correct or erroneous. As such, extra resolution in `trees` that is neither corroborated nor contradicted by `cf` is ignored.

Value

A data frame listing the ternary coordinates of trees, based on the amount of information that they have in common with the comparison tree (which defaults to the first member of the list, if unspecified).

Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

References

- Smith MR (2019). “Bayesian and parsimony approaches reconstruct informative trees from simulated morphological datasets.” *Biology Letters*, **15**(2), 20180632. doi:10.1098/rsbl.2018.0632.

Examples

```
library('Ternary')
data('sq_trees')

TernaryPlot(alab = 'Unresolved', blab = 'Contradicted', clab = 'Consistent',
            point = 'right')
TernaryLines(list(c(0, 2/3, 1/3), c(1, 0, 0)), col = 'red', lty = 'dotted')
TernaryText(QuartetPoints(sq_trees, cf = sq_trees$collapse_one), 1:15,
            col = Ternary::cbPalette8[2], cex = 0.8)
TernaryText(SplitPoints(sq_trees, cf = sq_trees$collapse_one), 1:15,
            col = Ternary::cbPalette8[3], cex = 0.8)
legend('bottomright', c("Quartets", "Splits"), bty = 'n', pch = 1, cex = 0.8,
      col = Ternary::cbPalette8[2:3])
```

QuartetState	<i>Quartet State(s)</i>
--------------	-------------------------

Description

Report the status of the specified quartet(s) in given trees or lists of splits.

Usage

```
QuartetState(tips, bips, splits = bips, asRaw = FALSE)
```

```
QuartetStates(splits, asRaw = FALSE)
```

```
## S3 method for class 'Splits'
QuartetStates(splits, asRaw = FALSE)
```

```
## S3 method for class 'list'
QuartetStates(splits, asRaw = FALSE)
```

```
## S3 method for class 'multiPhylo'
QuartetStates(splits, asRaw = FALSE)
```

Arguments

tips	A four-element array listing a quartet of leaves, either by their number (if class numeric) or their name (if class character).
bips	Deprecated; included for compatibility with v1.0.2 and below.

splits	An object, such as a tree of class <code>phylo</code> , that can be induced to a <code>Splits</code> object using <code>as.Splits</code> .
asRaw	Logical specifying whether return format should be raw, which uses less memory and can be processed faster than integer type. Default is currently set to FALSE for backwards compatibility; suggest overriding to TRUE.

Details

One of the three possible four-leaf trees will be consistent with any set of splits generated from a fully resolved tree. If the leaves are numbered 1 to 4, this tree can be identified by naming the leaf most closely related to leaf 4. If a set of splits is generated from a tree that contains polytomies, it is possible that all three four-leaf trees are consistent with the set of splits.

Value

`QuartetState()` returns 0 if the relationships of the four leaves are not constrained by the provided splits, or the index of the closest relative to `tips[4]`, otherwise.

`QuartetStates()` returns a raw vector listing the status of each quartet of leaves (in the order listed by `AllQuartets()`) in turn, or if multiple trees are provided, a matrix in which each row corresponds to such a vector.

Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

References

- Estabrook GF, McMorris FR, Meacham CA (1985). “Comparison of undirected phylogenetic trees based on subtrees of four evolutionary units.” *Systematic Zoology*, **34**(2), 193–200. [doi:10.2307/2413326](https://doi.org/10.2307/2413326).

See Also

Compare quartet states between trees (slowly) using `CompareQuartets()` and `CompareQuartetsMulti()`.

Other element-by-element comparisons: `CompareQuartetsMulti()`, `CompareQuartets()`, `CompareSplits()`, `PairSharedQuartetStatus()`, `SharedQuartetStatus()`, `SplitStatus()`

Examples

```
trees <- list(TreeTools::BalancedTree(6),
             TreeTools::PectinateTree(6))

trees[[3]] <- TreeTools::CollapseNode(trees[[2]], 9:10)

QuartetState(c(1, 3, 4, 6), trees[[2]])
QuartetState(1:4, trees[[1]]) == QuartetState(1:4, trees[[2]])
QuartetState(c(1, 3, 4, 6), trees[[3]])

QuartetStates(trees[[2]])
QuartetStates(trees[[3]])
```

```
CompareQuartets(QuartetStates(trees[[2]]), QuartetStates(trees[[3]]))
CompareQuartetsMulti(trees[[1]], trees[2:3])
```

ResolvedQuartets	<i>Count resolved quartets</i>
------------------	--------------------------------

Description

Counts how many quartets are resolved or unresolved in a given tree, following Brodal *et al.* (2013).

Usage

```
ResolvedQuartets(tree, countTriplets = FALSE)
```

```
ResolvedTriplets(tree)
```

Arguments

tree	A tree of class <code>phylo</code> .
countTriplets	Logical; if TRUE, the function will return the number of triplets instead of the number of quartets.

Details

Trees with more than 477 leaves risk encountering integer overflow errors, as the number of quartets is larger than can be stored in R's signed 32-bit integer representation. If warnings are thrown, check subsequent calculations for errors.

Value

`ResolvedQuartets()` returns a vector of length two, listing the number of quartets (or triplets) that are [1] resolved; [2] unresolved in the specified tree.

Functions

- `ResolvedTriplets`: Convenience function to calculate the number of resolved/unresolved triplets.

Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

References

- Brodal GS, Fagerberg R, Mailund T, Pedersen CNS, Sand A (2013). "Efficient algorithms for computing the triplet and quartet distance between trees of arbitrary degree." *SODA '13 Proceedings of the Twenty-Fourth Annual ACM-SIAM Symposium on Discrete Algorithms*, 1814–1832. doi:10.1137/1.9781611973105.130.

See Also

Other quartet counting functions: [AllQuartets\(\)](#), [CompareQuartetsMulti\(\)](#), [CompareQuartets\(\)](#)

Examples

```
data(sq_trees)

ResolvedTriplets(sq_trees$collapse_some)
# Equivalent to:
ResolvedQuartets(sq_trees$collapse_some, countTriplets = TRUE)

vapply(sq_trees, ResolvedQuartets, integer(2))
```

SharedQuartetStatus *Status of quartets*

Description

Determines the number of quartets that are consistent within pairs of trees.

Usage

```
SharedQuartetStatus(trees, cf = trees[[1]])

QuartetStatus(trees, cf = trees[[1]], nTip = NULL)

ManyToManyQuartetAgreement(trees, nTip = NULL)

TwoListQuartetAgreement(trees1, trees2)

SingleTreeQuartetAgreement(trees, comparison)
```

Arguments

trees	A list of trees of class phylo , with identically labelled tips.
cf	Comparison tree of class phylo . If unspecified, each tree is compared to the first tree in trees.
nTip	Integer specifying number of tips that could have occurred in trees. Useful if comparing trees from different data sources that contain non-overlapping tips. If NULL, the default, then trees are assumed to contain the same tips. If TRUE, then a vector is generated automatically by counting all unique tip labels found in trees or cf.
trees1, trees2	List or multiPhylo objects containing trees of class phylo .
comparison	A tree of class phylo against which to compare trees.

Details

Given a list of trees, returns the number of quartet statements present in the reference tree (the first entry in `trees`, if `cf` is not specified) that are also present in each other tree. A random pair of fully resolved trees is expected to share $\text{choose}(n_{\text{tip}}, 4) / 3$ quartets.

If trees do not bear the same number of tips, `SharedQuartetStatus()` will consider only the quartets that include taxa common to both trees.

From this information it is possible to calculate how many of all possible quartets occur in one tree or the other, though there is not yet a function calculating this; **let us know** if you would appreciate this functionality.

The status of each quartet is calculated using the algorithms of Brodal *et al.* (2013) and Holt *et al.* (2014), implemented in the `tqdist` C library (Sand *et al.* 2014).

Value

`QuartetStatus()` returns a two dimensional array. Rows correspond to the input trees; the first row will report a perfect match if the first tree is specified as the comparison tree (or if `cf` is not specified). Columns list the status of each quartet:

N The total number of quartet *statements* for two trees of n leaves, i.e. $2Q$.

Q The total number of quartets for n leaves.

s The number of quartets that are resolved identically in both trees.

d The number of quartets that are resolved differently in each tree.

r1 The number of quartets that are resolved in tree 1, but not in tree 2.

r2 The number of quartets that are resolved in tree 2, but not in tree 1.

u The number of quartets that are unresolved in both trees.

`ManyToManyQuartetAgreement()` returns a three-dimensional array listing, for each pair of trees in turn, the number of quartets in each category.

`TwoListQuartetAgreement()` returns a three-dimensional array listing, for each pair of trees in turn, the number of quartets in each category.

`SingleTreeQuartetAgreement()` returns a two-dimensional array listing, for tree in `trees`, the total number of quartets and the number of quartets in each category. The comparison tree is treated as `tree2`.

Functions

- `SharedQuartetStatus`: Reports split statistics obtained after removing all tips that do not occur in both trees being compared.
- `ManyToManyQuartetAgreement`: Agreement of each quartet, comparing each pair of trees in a list.
- `TwoListQuartetAgreement`: Agreement of each quartet in trees in one list with each quartet in trees in a second list.
- `SingleTreeQuartetAgreement`: Agreement of each quartet in trees in a list with the quartets in a comparison tree.

Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

References

- Brodal GS, Fagerberg R, Mailund T, Pedersen CNS, Sand A (2013). “Efficient algorithms for computing the triplet and quartet distance between trees of arbitrary degree.” *SODA '13 Proceedings of the Twenty-Fourth Annual ACM-SIAM Symposium on Discrete Algorithms*, 1814–1832. doi:10.1137/1.9781611973105.130.
- Estabrook GF, McMorris FR, Meacham CA (1985). “Comparison of undirected phylogenetic trees based on subtrees of four evolutionary units.” *Systematic Zoology*, **34**(2), 193–200. doi:10.2307/2413326.
- Holt MK, Johansen J, Brodal GS (2014). “On the scalability of computing triplet and quartet distances.” In *Proceedings of 16th Workshop on Algorithm Engineering and Experiments (ALENEX) Portland, Oregon, USA*.
- Sand A, Holt MK, Johansen J, Brodal GS, Mailund T, Pedersen CNS (2014). “tqDist: a library for computing the quartet and triplet distances between binary or general trees.” *Bioinformatics*, **30**(14), 2079–2080. ISSN 1460-2059, doi:10.1093/bioinformatics/btu157.

See Also

- Use splits (groups/clades defined by nodes or edges of the tree) instead of quartets as the unit of comparison: [SplitStatus\(\)](#).
- Generate distance metrics from quartet statuses: [SimilarityMetrics\(\)](#).

Other element-by-element comparisons: [CompareQuartetsMulti\(\)](#), [CompareQuartets\(\)](#), [CompareSplits\(\)](#), [PairSharedQuartetStatus\(\)](#), [QuartetState\(\)](#), [SplitStatus\(\)](#)

Examples

```
data('sq_trees')
# Calculate the status of each quartet relative to the first entry in
# sq_trees
sq_status <- QuartetStatus(sq_trees)

# Calculate the status of each quartet relative to a given tree
two_moved <- sq_trees[5:7]
sq_status <- QuartetStatus(two_moved, sq_trees$ref_tree)

# Calculate Estabrook et al's similarity measures:
SimilarityMetrics(sq_status)

# Compare trees that include a subset of the taxa 1..10
library('TreeTools', quietly = TRUE, warn.conflict = FALSE)
QuartetStatus(BalancedTree(1:5), BalancedTree(3:8), nTip = 10)

# If all taxa studied occur in `trees` or `cf`, set `nTip = TRUE`
QuartetStatus(BalancedTree(1:5), BalancedTree(3:10), nTip = TRUE)

# Calculate Quartet Divergence between each tree and each other tree in a
```

```
# list
QuartetDivergence(ManyToManyQuartetAgreement(two_moved))
# Calculate Quartet Divergence between each tree in one list and each
# tree in another
QuartetDivergence(TwoListQuartetAgreement(sq_trees[1:3], sq_trees[10:13]))
```

SimilarityMetrics *Tree similarity measures*

Description

Measure tree similarity or difference.

Usage

```
SimilarityMetrics(elementStatus, similarity = TRUE)
DoNotConflict(elementStatus, similarity = TRUE)
ExplicitlyAgree(elementStatus, similarity = TRUE)
StrictJointAssertions(elementStatus, similarity = TRUE)
SemiStrictJointAssertions(elementStatus, similarity = TRUE)
SymmetricDifference(elementStatus, similarity = TRUE)
RawSymmetricDifference(elementStatus, similarity = FALSE)
RobinsonFoulds(elementStatus, similarity = FALSE)
MarczewskiSteinhaus(elementStatus, similarity = TRUE)
SteelPenny(elementStatus, similarity = TRUE)
QuartetDivergence(elementStatus, similarity = TRUE)
SimilarityToReference(elementStatus, similarity = TRUE, normalize = FALSE)
```

Arguments

elementStatus Two-dimensional integer array, with rows corresponding to counts of matching quartets or partitions for each tree, and columns named according to the output of [QuartetStatus\(\)](#) or [SplitStatus\(\)](#).

similarity Logical specifying whether to calculate the similarity or dissimilarity.

normalize Logical; if TRUE, a random or star tree has expected similarity 0 (or difference 1), and the maximum possible score is one. If FALSE, zero similarity corresponds to all quartets contradicted, whereas one corresponds to all quartets correctly resolved – which will be unattainable if the reference tree contains polytomies.

Details

Estabrook et al. (1985) (table 2) define four similarity metrics in terms of the total number of quartets (N , their Q), the number of quartets resolved in the same manner in two trees (s), the number resolved differently in both trees (d), the number resolved in tree 1 or 2 but unresolved in the other tree ($r1$, $r2$), and the number that are unresolved in both trees (u).

The similarity metrics are then given as below. The dissimilarity metrics are their complement (i.e. $1 - \text{similarity}$), and can be calculated algebraically using the identity $N = s + d + r1 + r2 + u$.

Although defined using quartets, analogous values can be calculated using partitions – though for a number of reasons, quartets may offer a more meaningful measure of the amount of information shared by two trees (Smith 2020).

- Do Not Conflict (DC): $(s + r1 + r2 + u) / N$
- Explicitly Agree (EA): s / N
- Strict Joint Assertions (SJA): $s / (s + d)$
- SemiStrict Joint Assertions (SSJA): $s / (s + d + u)$

(The numerator of the SemiStrict Joint Assertions similarity metric is given in Estabrook et al. (1985) table 2 as $s + d$, but this is understood, with reference to their text, to be a typographic error.)

Steel and Penny (1993) propose a further metric, which they denote $d_Q_$, which this package calculates using the function `SteelPenny()`:

- Steel & Penny’s quartet metric (dQ): $(s + u) / N$

Another take on tree similarity is to consider the symmetric difference: that is, the number of partitions or quartets present in one tree that do not appear in the other, originally used to measure tree similarity by Robinson and Foulds (1981). (Note that, given the familiarity of the Robinson–Foulds distance metric, this quantity is by default expressed as a difference rather than a similarity.)

- Raw symmetric difference (RF): $d1 + d2 + r1 + r2$

A pair of trees will have a high symmetric difference if they are well-resolved but disagree on many relationships; or if they agree on most relationships but are poorly resolved. As such, it is essential to contextualize the symmetric difference by appropriate normalization (Smith 2019). Multiple approaches to normalization have been proposed:

The total number of resolved quartets or partitions present in both trees (Day 1986):

- Symmetric Difference (SD): $(2 d + r1 + r2) / (2 d + 2 s + r1 + r2)$

The total distinctly resolved quartets or partitions (Marczewski and Steinhaus 1958; Day 1986):

- Marczewski-Steinhaus (MS): $(2 d + r1 + r2) / (2 d + s + r1 + r2)$

The maximum number of quartets or partitions that could have been resolved, given the number of tips (Smith 2019):

- Symmetric Divergence: $(d + d + r1 + r2) / N$

Finally, in cases where a reconstructed tree $r1$ is being compared to a reference tree $r2$ taken to represent 'true' relationships, a symmetric difference is not desired. In such settings, the desired score is the expectation that a given quartet's resolution in the reconstructed tree is 'correct', given by Asher and Smith (2022):

- Similarity to Reference (S2R): $(s + (r1 + r2 + u) / 3) / Q$

This may optionally be normalized with reference to the maximum possible similarity, $(s + d + r2 + (r1 + u) / 3) / Q$, subtracting $1/3$ (the probability of matching at random) from both the S2R score and maximum possible score before dividing; then, a tree scores zero if it is as different from the true tree as a random or fully unresolved tree, and one if it is as 'true' as can be known.

Value

SimilarityMetrics() returns a named two-dimensional array in which each row corresponds to an input tree, and each column corresponds to one of the listed measures.

DoNotConflict() and others return a named vector describing the requested similarity (or difference) between the trees.

Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

References

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Steel MA, Penny D (1993). “Distributions of tree comparison metrics—some new results.” *Systematic Biology*, 42(2), 126–141. doi:10.1093/sysbio/42.2.126, http://www.math.canterbury.ac.nz/~m.steel/Non_UC/files/research/distributions.pdf.

See Also

- Calculate status of each quartet – the raw material from which the Estabrook *et al.* metrics are calculated – with `QuartetStatus()`:
- Equivalent metrics for bipartition splits: `SplitStatus()`, `CompareSplits()`

Examples

```
data('sq_trees')

sq_status <- QuartetStatus(sq_trees)
SimilarityMetrics(sq_status)
QuartetDivergence(sq_status, similarity = FALSE)

library('TreeTools', quietly = TRUE, warn.conflict = FALSE)
set.seed(0)
reference <- CollapseNode(as.phylo(101, 10), 16:18)
trees <- c(
  reference = reference,
  binaryRef = MakeTreeBinary(reference),
  balanced = BalancedTree(reference),
  pectinate = PectinateTree(reference),
  star = StarTree(reference),
  random = RandomTree(reference),
  random2 = RandomTree(reference)
)
elementStatus <- QuartetStatus(trees, reference)
SimilarityToReference(elementStatus)
SimilarityToReference(elementStatus, normalize = TRUE)
```

SplitStatus

Matching partitions

Description

Calculates how many of the partitions present in tree 1 are also present in tree 2 (s), how many of the partitions in tree 1 are absent in tree 2 (d1), and how many of the partitions in tree 2 are absent in tree 1 (d2). The Robinson-Foulds (symmetric partition) distance is the sum of the latter two quantities, i.e. d1 + d2.

Usage

```
SplitStatus(trees, cf = trees[[1]])

SharedSplitStatus(trees, cf)
```

Arguments

trees	A list of trees of class <code>phylo</code> , with identically labelled tips.
cf	Comparison tree of class <code>phylo</code> . If unspecified, each tree is compared to the first tree in trees.

Value

Returns a two dimensional array. Rows correspond to the input trees, and are named if names were present. Columns report:

N: The total number of partitions present in the two trees, i.e. $P1 + P2$.

P1: The number of partitions present in tree 1.

P2: The number of partitions present in tree 2.

s: The number of partitions present in both trees.

d1: The number of partitions present in tree 1, but contradicted by tree 2.

d2: The number of partitions present in tree 2, but contradicted by tree 1.

r1: The number of partitions present in tree 1, and neither present nor contradicted in tree 2.

r2: The number of partitions present in tree 2, and neither present nor contradicted in tree 1.

Functions

- `SharedSplitStatus`: Reports split statistics obtained after removing all tips that do not occur in both trees being compared.

Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

References

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See Also

Other element-by-element comparisons: `CompareQuartetsMulti()`, `CompareQuartets()`, `CompareSplits()`, `PairSharedQuartetStatus()`, `QuartetState()`, `SharedQuartetStatus()`

Examples

```
data('sq_trees')

# Calculate the status of each quartet
splitStatuses <- SplitStatus(sq_trees)

# Calculate the raw symmetric difference (i.e. RobinsonFoulds distance)
```

```

RawSymmetricDifference(splitStatuses)

# Normalize the Robinson Foulds distance by dividing by the number of
# splits present in the two trees:
RawSymmetricDifference(splitStatuses) / splitStatuses[, 'N']

# Normalize the Robinson Foulds distance by dividing by the total number of
# splits that it is possible to resolve for `n` tips:
nTip <- length(sq_trees[[1]]$tip.label)
nPartitions <- 2 * (nTip - 3L) # Does not include the nTip partitions that
# comprise but a single tip
RawSymmetricDifference(splitStatuses) / nPartitions

```

sq_trees

Eighteen example trees

Description

A list of class `multiPhylo` containing phylogenetic trees:

`ref_tree` A reference tree, bearing tips labelled 1 to 11.

`move_one_near` Tip 1 has been moved a short distance.

`move_one_mid` Tip 1 has been moved further.

`move_one_far` Tip 1 has been moved further still.

`move_two_near` Tips 10 & 11 have been moved a short distance.

`move_two_mid` Tips 10 & 11 have been moved further.

`move_two_far` Tips 10 & 11 have been moved further still.

`collapse_one` One node has been collapsed into a polytomy.

`collapse_some` Several nodes have been collapsed.

`m1mid_col1` Tree `move_one_mid` with one node collapsed.

`m1mid_colsome` Tree `move_one_mid` with several nodes collapsed.

`m2mid_col1` Tree `move_two_mid` with one node collapsed.

`m2mid_colsome` Tree `move_two_mid` with several nodes collapsed.

`opposite_tree` A tree that shares fewer quartets with `ref_tree` than expected by chance.

`caterpillar` A pectinate 'caterpillar' tree.

`top_and_tail` Tree `caterpillar`, with its outermost taxa swapped such that it shares no partitions with `caterpillar`.

`anti_pectinate` A random tree that shares no partitions with `caterpillar`.

`random_tree` A random tree.

Usage

```
sq_trees
```

Format

An object of class `multiPhylo` of length 18.

SymmetricDifferenceLineEnds

Plot contours of equal symmetric difference on a ternary plot

Description

Assumes that tree 1 is perfectly resolved, but that the resolution of tree 2 can vary.

Usage

```
SymmetricDifferenceLineEnds(nsd)
```

```
SymmetricDifferenceLines(nsd, ...)
```

Arguments

`nsd` Vector specifying normalized symmetric differences to plot.

`...` Further parameters to pass to [TernaryLines\(\)](#).

Value

Returns a matrix of dim $(\text{length}(\text{nsd}), 6)$, with columns named `r2a`, `da`, `sa`, `r2b`, `db` and `sb`. Lines from `a` to `b` in each row connect points of equal symmetric difference.

Functions

- `SymmetricDifferenceLines`: Plot the lines onto the active ternary plot.

Author(s)

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TQDist

Wrapper for tqDist

Description

Convenience function that takes a list of trees, writes them to the text file expected by the C implementation of tqDist (Sand *et al.* 2014). tqDist is then called, and the temporary file is deleted when analysis is complete.

Usage

TQDist(trees)

TQAE(trees)

Arguments

trees List of phylogenetic trees, of class `list` or `multiPhylo`.

Details

Quartets can be resolved in one of five ways, which Brodal *et al.* (2013) and Holt *et al.* (2014) distinguish using the letters A–E, and Estabrook *et al.* (1985) refers to as:

- A: s = resolved the same in both trees;
- B: d = resolved differently in both trees;
- C: $r1$ = resolved only in tree **1**;
- D: $r2$ = resolved only in tree **2** (the comparison tree);
- E: u = unresolved in both trees.

Value

TQDist() returns the quartet distance between each pair of trees.

TQAE() returns the number of resolved quartets in agreement between each pair of trees ('A' in Brodal *et al.* 2013) and the number of quartets that are unresolved in both trees ('E' in Brodal *et al.* 2013).

Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

References

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See Also

[CompareQuartets\(\)](#), [QuartetStatus\(\)](#)

VisualizeQuartets

Visualize quartet difference on trees, by split

Description

Visualize quartet difference on trees, by split

Usage

```
VisualizeQuartets(
  tree1,
  tree2,
  style = "pie",
  setPar = TRUE,
  precision = 3L,
  Plot = plot.phylo,
  scale = 1L,
  spectrum = viridisLite::viridis(101),
  legend = TRUE,
  ...
)
```

Arguments

tree1, tree2 Trees of class phylo, with identical leaf labels.
 style Character string specifying split labels with an unambiguous abbreviation of:

- label: Label stating proportion of resolved quartets in agreement, coloured accordingly;
- pie: Pie chart showing proportion of quartets in agreement, sized according to number of quartets influenced by each split;
- bar: Bar showing proportion of quartets in agreement, labelled;
- size: Circle coloured according to proportion of quartets in agreement, with area corresponding to number of quartet statements associated with split.

setPar	Logical specifying whether graphical parameters should be set to display trees side by side.
precision	Integer specifying number of significant figures to display when reporting matching scores.
Plot	Function to use to plot trees.
scale	Numeric, enlargement factor for split labels.
spectrum	101-element vector specifying a range of colours by which to colour matches.
legend	Logical specifying whether to display simple legend.
...	Additional parameters to send to Plot().

Author(s)

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Examples

```
library('TreeTools', quietly = TRUE, warn.conflicts = FALSE)
VisualizeQuartets(BalancedTree(10), CollapseNode(PectinateTree(10), 19),
  style = 'label')
# Keep original plotting parameters:
origPar <- par(mfrow = c(2, 2))
VisualizeQuartets(BalancedTree(10), CollapseNode(PectinateTree(10), 19),
  setPar = FALSE)
VisualizeQuartets(BalancedTree(10), CollapseNode(PectinateTree(10), 19),
  style = 'bar', legend = FALSE, setPar = FALSE)
par(origPar)
VisualizeQuartets(BalancedTree(20), CollapseNode(PectinateTree(20), 29:33),
  style = 'size', scale = 2)
```

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