Package 'rTwig'

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Title Realistic Quantitative Structure Models

Version 1.1.0

Description Real Twig is a method to correct branch overestimation in quantitative structure models. Overestimated cylinders are correctly tapered using measured twig diameters of corresponding tree species. Supported quantitative structure modeling software includes 'TreeQSM', 'SimpleForest' and 'Treegraph'. Also included is a novel database of twig diameters and tools for fractal analysis of point clouds.

Encoding UTF-8

RoxygenNote 7.3.2

RdMacros Rdpack

Imports R.matlab, rmatio, tidytable, cobs, igraph, future, foreach, doFuture, progressr, rgl, colourvalues, Rdpack, rlang, Rcpp, RcppSimdJson, geometry

License GPL (>= 3)

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VignetteBuilder knitr

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URL https://aidanmorales.github.io/rTwig/, https://github.com/aidanmorales/rTwig

BugReports https://github.com/aidanmorales/rTwig/issues

LinkingTo Rcpp

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Repository CRAN

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Contents

`box_dimension` *Box Dimension*

Description

R port of Dominik Seidel's fractal analysis "box-dimension" metric.

Usage

```
box_dimension(cloud, lowercutoff = 0.01, rm_int_box = FALSE, plot = FALSE)
```

Arguments

`cloud`	A point cloud matrix size n x 3. Non-matrices are automatically converted to a matrix.
`lowercutoff`	The smallest box size determined by the point spacing of the cloud in meters. Defaults to 1 cm.
`rm_int_box`	Remove the initial box as TRUE or FALSE. Defaults to FALSE.
`plot`	Plot the results. The user can specify "2D", "3D", or "ALL" plots. FALSE disables plotting. Defaults to FALSE.

Value

Returns a list

References

Arseniou G, MacFarlane DW, Seidel D (2021). "Measuring the Contribution of Leaves to the Structural Complexity of Urban Tree Crowns with Terrestrial Laser Scanning." *Remote Sensing*, **13**(14). doi:10.3390/rs13142773.

Mandelbrot BB (1983). *The fractal geometry of nature*. Freeman.

Saarinen N, Calders K, Kankare V, Yrttimaa T, Junttila S, Luoma V, Huuskonen S, Hynynen J, Verbeeck H (2021). "Understanding 3D structural complexity of individual Scots pine trees with different management history." *Ecology and Evolution*, **11**(6), 2561-2572. doi:10.1002/ece3.7216.

Seidel D (2018). "A holistic approach to determine tree structural complexity based on laser scanning data and fractal analysis." *Ecology and Evolution*, **8**(1), 128-134. doi:10.1002/ece3.3661.

Seidel D, Annighöfer P, Stiers M, Zemp CD, Burkardt K, Ehbrecht M, Willim K, Kreft H, Hölscher D, Ammer C (2019). "How a measure of tree structural complexity relates to architectural benefit-to-cost ratio, light availability, and growth of trees." *Ecology and Evolution*, **9**(12), 7134-7142. doi:10.1002/ece3.5281.

Examples

```
## Calculate Box Dimension
file <- system.file("extdata/cloud.txt", package = "rTwig")
cloud <- read.table(file, header = FALSE)
output <- box_dimension(cloud, plot = "ALL")
output
```

`correct_radii` *Correct Radii*

Description

Corrects cylinder radii

Usage

```
correct_radii(cylinder, twig_radius, backend = "multisession")
```

Arguments

`cylinder`	QSM cylinder data frame
`twig_radius`	Twig radius in millimeters
`backend`	Parallel backend for multi-core processing. Defaults to "multisession" (all platforms), but can be set to "multicore" (MacOS & Linux), "cluster" (all platforms), or a "package::backend" string.

Value

Returns a data frame

Examples

```
## TreeQSM Processing Chain
file <- system.file("extdata/QSM.mat", package = "rTwig")
qsm <- import_qsm(file)
cylinder <- qsm$cylinder
cylinder <- update_cylinders(cylinder)
cylinder <- correct_radii(cylinder, twig_radius = 4.23)
str(cylinder)

## SimpleForest Processing Chain
file <- system.file("extdata/QSM.csv", package = "rTwig")
cylinder <- read.csv(file)
cylinder <- update_cylinders(cylinder)
cylinder <- correct_radii(cylinder, twig_radius = 4.23)
str(cylinder)
```

`export_mat` *Export MAT*

Description

Exports the cylinder data to be visualized with TreeQSM's plot_cylinder_model() function

Usage

```
export_mat(cylinder, filename)
```

Arguments

`cylinder`	QSM cylinder data frame
`filename`	Desired name of file

Value

Returns a .mat file

Examples

```
## TreeQSM Processing Chain
file <- system.file("extdata/QSM.mat", package = "rTwig")
qsm <- import_qsm(file)
cylinder <- qsm$cylinder
cylinder <- update_cylinders(cylinder)

filename <- tempfile(pattern = "TreeQSM_QSM.mat")
```

```
export_mat(cylinder, filename)

## SimpleForest Processing Chain
file <- system.file("extdata/QSM.csv", package = "rTwig")
cylinder <- read.csv(file)
cylinder <- update_cylinders(cylinder)

filename <- tempfile(pattern = "SimpleForest_QSM.mat")
export_mat(cylinder, filename)
```

`export_mesh` *Export Mesh*

Description

Exports QSM cylinder mesh using the rgl library

Usage

```
export_mesh(
  cylinder,
  filename,
  radius = NULL,
  color = NULL,
  palette = NULL,
  facets = 6,
  normals = FALSE
)
```

Arguments

`cylinder`	QSM cylinder data frame
`filename`	File name and path for exporting. The .ply extension is automatically added if not present.
`radius`	Vector of cylinder radii. Defaults to modified cylinders from the cylinder data frame.
`color`	Optional cylinder color parameter. Colors must be a single hex color, a vector of hex colors, or a quoted column name. It can also be set to "random" to generate a random solid color, or FALSE to disable color on export. Vectors must have the same length as the cylinder data frame.
`palette`	Optional color palette for numerical data. Palettes include: viridis, inferno, plasma, magma, cividis, and rainbow.
`facets`	The number of facets in the polygon cross section. Defaults to 6, but can be increased to improve visual smoothness at the cost of performance and memory.
`normals`	Option to export normals. Defaults to FALSE, but can be set to TRUE.

Value

A mesh .ply file

Examples

```
## TreeQSM Processing Chain
file <- system.file("extdata/QSM.mat", package = "rTwig")
qsm <- import_qsm(file)
cylinder <- qsm$cylinder
cylinder <- update_cylinders(cylinder)

filename <- tempfile(pattern = "QSM_mesh")
export_mesh(cylinder, filename)

## SimpleForest Processing Chain
file <- system.file("extdata/QSM.csv", package = "rTwig")
cylinder2 <- read.csv(file)
cylinder2 <- update_cylinders(cylinder2)

filename2 <- tempfile(pattern = "QSM_mesh2")
export_mesh(cylinder2, filename2)

## All Parameters

filename3 <- tempfile(pattern = "QSM_mesh3")
export_mesh(
  cylinder = cylinder,
  filename = filename3,
  radius = "UnmodRadius",
  color = "growthLength",
  palette = "viridis"
)
```

---

import_qsm *Import TreeQSM*

Description

Imports a QSM created by TreeQSM

Usage

```
import_qsm(file, version = "2.x.x")
```

Arguments

file	a TreeQSM .mat MATLAB file
version	TreeQSM version. Defaults to 2.x.x. The user can also specify the 2.0 format.

Value

Returns a list

References

Raumonen P, Kaasalainen M, Åkerblom M, Kaasalainen S, Kaartinen H, Vastaranta M, Holopainen M, Disney M, Lewis P (2013). "Fast Automatic Precision Tree Models from Terrestrial Laser Scanner Data." *Remote Sensing*, **5**(2), 491–520. doi:10.3390/rs5020491.

Examples

```
## Read a TreeQSM MATLAB file in the 2.3.x - 2.4.x format
file <- system.file("extdata/QSM.mat", package = "rTwig")
qsm <- import_qsm(file, version = "2.x.x")
summary(qsm)

## Read a TreeQSM MATLAB file in the 2.0 format
file <- system.file("extdata/QSM_2.mat", package = "rTwig")
qsm <- import_qsm(file, version = "2.0")
names(qsm)
```

---

import_treegraph *Import Treegraph*

Description

Imports a QSM created by treegraph

Usage

```
import_treegraph(file)
```

Arguments

file	a treegraph .json file

Value

Returns a list

References

Yang W, Wilkes P, Vicari MB, Hand K, Calders K, Disney M (2024). "Treegraph: tree architecture from terrestrial laser scanning point clouds." *Remote Sensing in Ecology and Conservation*. ISSN 2056-3485, doi:10.1002/rse2.399.

Wilkes P, Shenkin A, Disney M, Malhi Y, Bentley LP, Vicari MB (2021). "Terrestrial laser scanning to reconstruct branch architecture from harvested branches." *Methods in Ecology and Evolution*, **12**, 2487-2500. doi:10.1111/2041210X.13709.

Examples

```
## Not run:

# Import a treegraph QSM
qsm <- import_treegraph("path/to/json/file")

## End(Not run)
```

`plot_qsm` *Plot QSM*

Description

Plots QSM cylinders and point clouds using the rgl library

Usage

```
plot_qsm(
  cylinder,
  radius = NULL,
  color = NULL,
  palette = NULL,
  facets = 6,
  cloud = NULL,
  pt_color = NULL,
  pt_size = NULL,
  axes = TRUE,
  hover = FALSE,
  skeleton = FALSE,
  bg_color = NULL
)
```

Arguments

`cylinder`	QSM cylinder data frame
`radius`	Column name of radii as a quoted string. Defaults to the modified radii.
`color`	Optional cylinder color parameter. Colors must be a single hex color, a vector of hex colors, or a quoted column name. It can also be set to "random" to generate a random solid color. Vectors must have the same length as the cylinder data frame.
`palette`	Optional color palette for numerical data. Palettes include: viridis, inferno, plasma, magma, cividis, and rainbow.
`facets`	The number of facets in the polygon cross section. Defaults to 6, but can be increased to improve visual smoothness at the cost of performance and memory.

cloud	Point cloud data frame where the first three columns are the x, y, and z coordinates in the same coordinate system as the QSM. Defaults to NULL.
pt_color	Color of the point cloud. Defaults to black. Can be set to "random".
pt_size	Size of the points. Defaults to 0.1.
axes	Show plot axes. Defaults to TRUE.
hover	Show cylinder and branch id on mouse hover. Defaults to FALSE.
skeleton	Plot the QSM skeleton instead of cylinders. Defaults to FALSE.
bg_color	Set the background color of the rgl plot. Defaults to NULL.

Value

A rgl plot

Examples

```
## TreeQSM Processing Chain
file <- system.file("extdata/QSM.mat", package = "rTwig")
qsm <- import_qsm(file)
cylinder <- qsm$cylinder
cylinder <- update_cylinders(cylinder)
plot_qsm(cylinder)

## SimpleForest Processing Chain
file <- system.file("extdata/QSM.csv", package = "rTwig")
cylinder2 <- read.csv(file)
cylinder2 <- update_cylinders(cylinder2)
plot_qsm(cylinder2)

## All Parameters
file2 <- system.file("extdata/cloud.txt", package = "rTwig")
cloud <- read.table(file2, header = FALSE)

plot_qsm(
  cylinder,
  radius = "UnmodRadius",
  color = "growthLength",
  palette = "viridis",
  facets = 100,
  cloud = cloud,
  pt_color = "random",
  pt_size = 1,
  axes = FALSE,
  hover = TRUE,
  bg_color = "black"
)
```

qsm_summary *QSM Summary*

Description

Generates summaries of QSM features (e.g. volume, surface area, dbh, etc.) by totals and branch order

Usage

```
qsm_summary(cylinder, radius = "modified", triangulation = FALSE)
```

Arguments

cylinder	QSM cylinder data frame
radius	Radius type as either "modified", "unmodified", or "old". Defaults to "modified".
triangulation	QSM triangulation list. Defaults to FALSE.

Value

Returns a list

Examples

```
## TreeQSM Processing Chain
file <- system.file("extdata/QSM.mat", package = "rTwig")
qsm <- import_qsm(file)
cylinder <- qsm$cylinder
cylinder <- update_cylinders(cylinder)
qsm_summary(cylinder)

# TreeQSM Triangulation
file <- system.file("extdata/QSM.mat", package = "rTwig")
qsm <- import_qsm(file)
cylinder <- qsm$cylinder
cylinder <- update_cylinders(cylinder)
triangulation <- qsm$triangulation
qsm_summary(cylinder = cylinder, triangulation = triangulation)

## SimpleForest Processing Chain
file <- system.file("extdata/QSM.csv", package = "rTwig")
cylinder <- read.csv(file)
cylinder <- update_cylinders(cylinder)
qsm_summary(cylinder)
```

run_rtwig *Run Real Twig*

Description

Runs all Real Twig steps

Usage

```
run_rtwig(
  file,
  twig_radius,
  backend = "multisession",
  metrics = TRUE,
  version = NULL,
  smooth = TRUE,
  standardize = FALSE
)
```

Arguments

file	file path to QSM (.mat, .csv, .json)
twig_radius	Twig radius in millimeters
backend	Parallel backend for multi-core processing. Defaults to "multisession" (all platforms), but can be set to "multicore" (MacOS & Linux), "cluster" (all platforms), or a "package::backend" string.
metrics	Calculate tree metrics? Defaults to TRUE.
version	Defaults to NULL. If using a specific version of TreeQSM, the user can specify the version (e.g. 2.4.1, 2.0, etc.).
smooth	Defaults to TRUE, if using TreeQSM. Can be set to FALSE.
standardize	Standardize QSM cylinder data? Defaults to FALSE. Can be set to TRUE.

Value

Returns cylinder data frame or list if metrics is true.

Examples

```
## TreeQSM
file <- system.file("extdata/QSM.mat", package = "rTwig")
qsm <- run_rtwig(file, twig_radius = 4.23)
str(qsm$cylinder)

## SimpleForest
file <- system.file("extdata/QSM.csv", package = "rTwig")
```

```
qsm <- run_rtwig(file, twig_radius = 4.23)
str(qsm)
```

`smooth_qsm` *Smooth QSM*

Description

Visual smoothing of a QSM by ensuring the midpoints of all cylinders are connected

Usage

```
smooth_qsm(cylinder)
```

Arguments

`cylinder`	QSM cylinder data frame

Value

Returns a data frame

Examples

```
file <- system.file("extdata/QSM.mat", package = "rTwig")
qsm <- import_qsm(file)
cylinder <- qsm$cylinder
cylinder <- update_cylinders(cylinder)

## Before Smoothing
plot_qsm(cylinder)

## After Smoothing
cylinder <- smooth_qsm(cylinder)
plot_qsm(cylinder)
```

`standardize_qsm` *Standardize QSM*

Description

Standardizes QSM variable names and ordering across different QSM software

Usage

```
standardize_qsm(cylinder)
```

Arguments

`cylinder`	QSM cylinder data frame

Details

Renames supported QSM software output columns to be consistent. All names are lower case and underscore delimited. See the dictionary vignette for a detailed description of column names. A consistent QSM format ensures maximum compatibility when analyzing QSMs made with different software. This function can be run either before or after the update_cylinders function has been run, or at any stage.

Value

Returns a data frame

Examples

```
## TreeQSM Processing Chain
file <- system.file("extdata/QSM.mat", package = "rTwig")
qsm <- import_qsm(file)
cylinder <- qsm$cylinder
cylinder <- standardize_qsm(cylinder)
str(cylinder)

## SimpleForest Processing Chain
file <- system.file("extdata/QSM.csv", package = "rTwig")
cylinder <- read.csv(file)
cylinder <- standardize_qsm(cylinder)
str(cylinder)
```

`tree_metrics` *Tree Metrics*

Description

Calculates tree metrics from a QSM

Usage

```
tree_metrics(cylinder)
```

Arguments

`cylinder`	QSM cylinder data frame

Details

Calculates detailed tree, branch, and segment metrics from a QSM. The outputs include all of the standard outputs from TreeQSM, and also additional variables, including, but not limited to, growth length, reverse branch order, branch segment or node relationships, and distances from twigs and the base of the tree, across various distribution metrics. Also included is a simulated point cloud of the tree, based on the QSM cylinder radii. When corrected with Real Twig, this allow for the testing and validation of point cloud diameter overestimation throughout the tree.

Value

Returns a list of tree metric data frames and synthetic point cloud

References

Raumonen P, Kaasalainen M, Åkerblom M, Kaasalainen S, Kaartinen H, Vastaranta M, Holopainen M, Disney M, Lewis P (2013). "Fast Automatic Precision Tree Models from Terrestrial Laser Scanner Data." *Remote Sensing*, **5**(2), 491–520. doi:10.3390/rs5020491.

Hackenberg J, Spiecker H, Calders K, Disney M, Raumonen P (2015). "SimpleTree —An Efficient Open Source Tool to Build Tree Models from TLS Clouds." *Forests*, **6**(11), 4245–4294. doi:10.3390/f6114245.

Hackenberg J, Bontemps J (2023). "Improving quantitative structure models with filters based on allometric scaling theory." *Applied Geomatics*, **15**. doi:10.1007/s12518023005374.

Yang W, Wilkes P, Vicari MB, Hand K, Calders K, Disney M (2024). "Treegraph: tree architecture from terrestrial laser scanning point clouds." *Remote Sensing in Ecology and Conservation*. ISSN 2056-3485, doi:10.1002/rse2.399.

Examples

```
## TreeQSM Processing Chain
file <- system.file("extdata/QSM.mat", package = "rTwig")
cylinder <- import_qsm(file)$cylinder
cylinder <- update_cylinders(cylinder)
metrics <- tree_metrics(cylinder)
names(metrics)

## SimpleForest Processing Chain
file <- system.file("extdata/QSM.csv", package = "rTwig")
cylinder <- read.csv(file)
cylinder <- update_cylinders(cylinder)
metrics <- tree_metrics(cylinder)
names(metrics)
```

---

twigs *Twig Database*

Description

Database of twig radii for common North American tree species

Usage

```
twigs
```

Format

`twigs`**:**
A data frame containing twig radii measurements

scientific_name The tree's genus and species

radius_mm The average twig radius in millimeters

n The twig measurement sample size

min The minimum twig radii from the samples

max The maximum twig radii from the samples

std The standard deviation of twig radii

cv The coefficient of variation of twig radii

`update_cylinders` *Update Cylinders*

Description

Updates the QSM cylinder data in preparation for radii correction

Usage

```
update_cylinders(cylinder)
```

Arguments

`cylinder`	QSM cylinder data frame

Details

Updates parent-child branch and cylinder relationships to fill in any gaps. Four useful QSM metrics developed by Jan Hackenberg are also calculated. Growth length is the length of a parent cylinder, plus the lengths of all of its child cylinders. The segment is a portion of a branch between two branching nodes. The reverse branch order assigns twigs as order 1 and works backwards at each branching junction to the base of the stem, which has the largest reverse branch order. Distance from twig is the average distance to all connected twigs for a given cylinder. Two new metrics, distance from base, and total children, are also calculated.

Value

Returns a data frame

References

Hackenberg J, Spiecker H, Calders K, Disney M, Raumonen P (2015). "SimpleTree —An Efficient Open Source Tool to Build Tree Models from TLS Clouds." *Forests*, **6**(11), 4245–4294. doi:10.3390/f6114245.

Hackenberg J, Bontemps J (2023). "Improving quantitative structure models with filters based on allometric scaling theory." *Applied Geomatics*, **15**. doi:10.1007/s12518023005374.

Examples

```
## TreeQSM Processing Chain
file <- system.file("extdata/QSM.mat", package = "rTwig")
qsm <- import_qsm(file)
cylinder <- qsm$cylinder
cylinder <- update_cylinders(cylinder)
str(cylinder)

## SimpleForest Processing Chain
file <- system.file("extdata/QSM.csv", package = "rTwig")
```

```
cylinder <- read.csv(file)
cylinder <- update_cylinders(cylinder)
str(cylinder)
```

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