

Package ‘rTwig’

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Title Realistic Quantitative Structure Models

Version 1.0.2

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 'Tree-QSM' and 'SimpleForest'. Also included is a novel database of twig diameters and tools for fractal analysis of point clouds.

Encoding UTF-8

RoxygenNote 7.3.1

RdMacros Rdpack

Imports igraph, R.matlab, tidytable, data.table, cobs, purrr, foreach, future, doFuture, progressr, rgl, colourvalues, Morpho, Rdpack, DescTools, kit, rmatio, Matrix ($\geq 1.6-3$), randomcoloR

License GPL (≥ 3)

Depends R ($\geq 3.5.0$)

LazyData true

Suggests knitr, rmarkdown, ggplot2, ggpmisc, ggpubr, gt, yardstick, dplyr, tidyr

VignetteBuilder knitr

NeedsCompilation no

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<https://github.com/aidanmorales/rTwig>

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

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box_dimension	<i>Box Dimension</i>
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Description

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

Usage

```
box_dimension(
  cloud,
  x = 1,
  y = 2,
  z = 3,
  lowercutoff = 0.01,
  rm_int_box = FALSE,
  plot = FALSE
)
```

Arguments

cloud	A point cloud object
x	The column name or position of the x coordinates. Defaults to the first column.
y	The column name or position of the y coordinates. Defaults to the second column.
z	The column name or position of the x coordinates. Defaults to the third column.
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, twigRad, backend = "multisession")
```

Arguments

cylinder	QSM cylinder data frame
twigRad	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_radri(cylinder, twigRad = 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_radri(cylinder, twigRad = 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,
  cyl_color = NULL,
  cyl_palette = NULL,
  cyl_sides = 8
)
```

Arguments

cylinder	QSM cylinder data frame
filename	Desired name of file. The .ply extension is automatically added.
radius	Vector of cylinder radii. Defaults to modified cylinders from the cylinder data frame.

cyl_color	Optional cylinder color parameter. Colors must be a single hex color, or a vector or column of hex colors with the same length as the cylinder data frame.
cyl_palette	Optional color palette for numerical data. Palettes include: viridis, inferno, plasma, magma, cividis, and rainbow.
cyl_sides	The number of sides in the polygon cross section. Defaults to 8, but can be increased to improve visual smoothness.

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 = cylinder$UnmodRadius,
  cyl_color = cylinder$GrowthLength,
  cyl_palette = "viridis"
)
```

import_qsm	<i>Import QSM</i>
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Description

Imports a QSM created by TreeQSM

Usage

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

Arguments

file	a .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

Raunonen 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](https://doi.org/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)
```

plot_qsm

Plot QSM

Description

Plots QSM cylinders using the rgl library

Usage

```
plot_qsm(
  cylinder,
  radius = NULL,
  cyl_color = NULL,
  cyl_palette = NULL,
  cyl_sides = 8,
  cloud = NULL,
  pt_color = NULL,
  pt_size = NULL,
  axes = TRUE,
  hover = FALSE
)
```

Arguments

cylinder	QSM cylinder data frame
radius	Vector of cylinder radii. Defaults to modified cylinders from the cylinder data frame.
cyl_color	Optional cylinder color parameter. Colors must be a single hex color, or a vector or column of hex colors with the same length as the cylinder data frame.
cyl_palette	Optional color palette for numerical data. Palettes include: viridis, inferno, plasma, magma, cividis, and rainbow.
cyl_sides	The number of sides in the polygon cross section. Defaults to 8, but can be increased to improve visual smoothness.
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.
pt_color	Color of the point cloud. Defaults to black.
pt_size	Size of the points as a number. Defaults to 0.1.
axes	Show plot axes. Defaults to TRUE.
hover	Show cylinder ID and branch on mouse hover. Defaults to FALSE.

Value

A rgl QSM plot

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, twigRad = 4.23)
plot_qsm(cylinder)

## SimpleForest Processing Chain
file <- system.file("extdata/QSM.csv", package = "rTwig")
cylinder2 <- read.csv(file)
cylinder2 <- update_cylinders(cylinder2)
cylinder2 <- correct_radii(cylinder2, twigRad = 4.23)
plot_qsm(cylinder2)

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

plot_qsm(
  cylinder,
  radius = cylinder$UnmodRadius,
  cyl_color = cylinder$GrowthLength,
  cyl_palette = "viridis",
  cyl_sides = 100,
  cloud = cloud,
  pt_color = "white",
  pt_size = 1,
  axes = FALSE,
  hover = TRUE
)

```

plot_stand

Plot Stand

Description

Plots multiple QSMs in a forest stand using the rgl library

Usage

```

plot_stand(
  qsms,

```

```

radius_type = "modified",
qsm_colors = NULL,
cyl_sides = 8,
clouds = NULL,
pt_colors = NULL,
pt_sizes = NULL,
axes = TRUE
)

```

Arguments

qsms	A list of QSM cylinder data frames.
radius_type	Radius type as either "modified", "unmodified", or "old". Defaults to "modified".
qsm_colors	Optional qsm color parameters. Colors vector of hex colors with the same length as the qsms list. Defaults to distinct random colors.
cyl_sides	The number of sides in the polygon cross section. Defaults to 8, but can be increased to improve visual smoothness.
clouds	A list of point cloud data frames where the first three columns are the x, y, and z coordinates in the same coordinate system as the QSMs.
pt_colors	A vector of hex colors. Defaults to the same random color as the QSM.
pt_sizes	Size of the points as a number. Defaults to 0.1.
axes	Show plot axes. Defaults to TRUE.

Value

A rgl QSM plot

Examples

```

# Import QSMs
file1 <- system.file("extdata/QSM.mat", package = "rTwig")
qsm <- import_qsm(file1)
cylinder <- qsm$cylinder
cylinder <- update_cylinders(cylinder)

# Create a list of QSM cylinder data frames
qsms <- list(cylinder)

# Optionally import and create a list of point clouds
file2 <- system.file("extdata/cloud.txt", package = "rTwig")
cloud <- read.table(file2, header = FALSE)
clouds <- list(cloud)

# Plot QSMs and clouds
plot_stand(qsms = qsms, clouds = clouds)

```

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)
```

`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)
```

`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	<i>Update Cylinders</i>
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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. Three additional 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.

Value

Returns a data frame

References

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