

Package ‘doolkit’

July 22, 2025

Title Exploration of Dental Surface Topography

Version 1.42.2

Description Tools for exploring the topography of 3d triangle meshes.

The functions were developed with dental surfaces in mind, but could be applied to any triangle mesh of class 'mesh3d'. More specifically, 'doolkit' allows to isolate the border of a mesh, or a subpart of the mesh using the polygon networks method; crop a mesh; compute basic descriptors (elevation, orientation, footprint area); compute slope, angularity and relief index (Ungar and Williamson (2000) <https://palaeo-electronica.org/2000_1/gorilla/issue1_00.htm>; Boyer (2008) <[doi:10.1016/j.jhevol.2008.08.002](https://doi.org/10.1016/j.jhevol.2008.08.002)>), inclination and occlusal relief index or gamma (Guy et al. (2013) <[doi:10.1371/journal.pone.0066142](https://doi.org/10.1371/journal.pone.0066142)>), OPC (Evans et al. (2007) <[doi:10.1038/nature05433](https://doi.org/10.1038/nature05433)>), OPCR (Wilson et al. (2012) <[doi:10.1038/nature10880](https://doi.org/10.1038/nature10880)>), DNE (Bunn et al. (2011) <[doi:10.1002/ajpa.21489](https://doi.org/10.1002/ajpa.21489)>; Pampush et al. (2016) <[doi:10.1007/s10914-016-9326-0](https://doi.org/10.1007/s10914-016-9326-0)>), form factor (Horton (1932) <[doi:10.1029/TR013i001p00350](https://doi.org/10.1029/TR013i001p00350)>), basin elongation (Schum (1956) <[doi:10.1130/0016-7606\(1956\)67\[597:EODSAS\]2.0.CO;2](https://doi.org/10.1130/0016-7606(1956)67[597:EODSAS]2.0.CO;2)>), lemniscate ratio (Chorley et al; (1957) <[doi:10.2475/ajs.255.2.138](https://doi.org/10.2475/ajs.255.2.138)>), enamel-dentine distance (Guy et al. (2015) <[doi:10.1371/journal.pone.0138802](https://doi.org/10.1371/journal.pone.0138802)>; Thiery et al. (2017) <[doi:10.3389/fphys.2017.00524](https://doi.org/10.3389/fphys.2017.00524)>), absolute crown strength (Schwartz et al. (2020) <[doi:10.1098/rsbl.2019.0671](https://doi.org/10.1098/rsbl.2019.0671)>), relief rate (Thiery et al. (2019) <[doi:10.1002/ajpa.23916](https://doi.org/10.1002/ajpa.23916)>) and area-relative curvature; draw cumulative profiles of a topographic variable; and map a variable over a 3d triangle mesh.

License GPL-3

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angularity	<i>angularity</i>
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Description

Compute the angularity (delta slope).

Usage

angularity(mesh, ratio = FALSE)

Arguments

mesh	object of class mesh3d
ratio	logical, if false standard angularity will be computed (default), if true a relative angularity ratio will be computed (see below)

Value

If ratio = FALSE, a numeric vector of angularity values i.e. delta slope of each polygon compared to their adjacent polygons, for all the polygons of the mesh. If ratio = TRUE, a numeric vector of angularity ratio values. Ratio is computed by dividing polygon slope by 90, replacing vertex elevation by the average ratio of faces adjacent to the vertex, then dividing the slope of polygons from this new mesh by 90. Although it is a non-standard variable, it was implemented because it better discriminates sharp edges than basic angularity. Warning: both options can take up a significant amount of time for large meshes.

References

Ungar and Williamson (2000)

Examples

```
delta_slope <- angularity(dkmodel$complex, ratio = FALSE)
summary(delta_slope)
#angularity ratio:
delta_slope_ratio <- angularity(dkmodel$complex, ratio = TRUE)
summary(delta_slope_ratio)

#render on a map:
dkmap(dkmodel$complex, delta_slope, col = "slope",
      legend.lab = "Angularity (°)")
#angularity ratio:
dkmap(dkmodel$complex, delta_slope_ratio, col = "slope",
      legend.lab = "Angularity ratio")
```

arc	<i>Average-Relative Curvature (ARC)</i>
-----	---

Description

Compute a scale-free estimate of mean curvature.

Usage

```
arc(mesh, range = c(0.01, 0.99))
```

Arguments

mesh	object of class mesh3d
range	a numeric vector of the form <code>c('minrange', 'maxrange')</code> indicating the set limits for extreme values, beyond which arc values will be truncated. If 'minrange' and 'maxrange' are comprised between 0 and 1, they are used as arc percentages. If 'minrange' and 'maxrange' are not comprised between 0 and 1, they are used as raw arc values

Details

Area-relative curvature (ARC) is obtained by dividing the mean curvature of each triangle by the mean curvature of an hemisphere, the surface area of which is the same as the surface area of the total mesh object. Coincidentally, the surface area of a hemisphere is linked to its mean curvature by the following function: $2.4481 * 1 / \text{square root}(\text{surface area})$. As a result, ARC is a scale-free estimate of surface curvature. It can be used to estimate the sharpness of a mesh.

Value

A numeric vector of area-relative curvature values for all the polygons of the mesh.

Examples

```
curvature <- arc(dkmodel$complex)
summary(curvature)

#There is a default truncature of extreme values below 1% or above 99%.
#Without truncature:
curvature <- arc(dkmodel$complex, range = c(0, 1))
summary(curvature)

#mean positive ARC:
parc <- mean(curvature[curvature >= 0])
#mean negative ARC:
narc <- mean(curvature[curvature < 0])

#render on a map:
dkmap(dkmodel$complex, curvature, col = "arc",
min.range = -20, max.range = 20)
#absolute truncature of the values above 20 or below -20:
dkmap(dkmodel$complex, curvature, col = "arc", min.range = -20, max.range = 20)
```

area2d

2D surface area

Description

Compute the area of a 2d projection on the (xy) plane.

Usage

```
area2d(mesh, method = "concave")
```

Arguments

mesh	object of class mesh3d
method	the method used to compute the hull of the 2d projection, either 'convex' (see chull), or 'concave' (see concaveman). The default method is 'concave'.

Details

This function can assess 2D surface area of the projection of a mesh on the (xy) plane. The projection is assimilated to a hull, which can be a convex hull (see [chull](#)) or a concave hull (see [concaveman](#)). Note that if your mesh is a combination of two or more discontinuous surfaces (e.g., isolated cusps), you should not use either approach. As of version 1.42.2, the concave hull fails intermittently on Mac systems, so the function defaults to convex hulls (on other systems, it defaults to concave hulls)

Value

A single 2D surface area value, corresponding to the footprint of the mesh.

See Also

[rfi](#)

Examples

```
#The following objects should have the exact same footprints:
area2d(dkmodel$basin)
area2d(dkmodel$complex)
area2d(dkmodel$curv)
area2d(dkmodel$flat)

#Graphical rendering of convex hull
x <- dkmodel$curv
FootprintVerts <- t(x$vb[1:2, ])
Hull <- grDevices::chull(x = FootprintVerts[, 1], y = FootprintVerts[, 2])
plot(x$vb[1, ], x$vb[2, ], xlab = "x", ylab = "y")
points(x$vb[1, Hull], x$vb[2, Hull], col = "orange1")

#Graphical rendering of concave hull
x <- dkmodel$curv
FootprintVerts <- t(x$vb[1:2, ])
FootprintVerts[, 1] <- FootprintVerts[, 1] - min(FootprintVerts[, 1])
FootprintVerts[, 2] <- FootprintVerts[, 2] - min(FootprintVerts[, 2])
Hull <- concaveman::concaveman(points = FootprintVerts)
plot(x$vb[1, ] - min(x$vb[1, ]), x$vb[2, ] - min(x$vb[2, ]), xlab = "x", ylab = "y")
points(Hull, col = "green1")
```

dkborder

dkborder

Description

Selects the border of a 3d triangle mesh.

Usage

```
dkborder(mesh)
```

Arguments

mesh object of class mesh3d

Value

A vector of indices corresponding to the triangles with at least one vertex on the border of the mesh.

Examples

```
border <- dkborder(dkmodel$culp)

# Map the border in orange:
is_border <- rep(1, Rvcg::nfaces(dkmodel$culp))
is_border[border] <- 2
dkmap(dkmodel$culp, is_border, col = c("white", "#E69F00"), col.levels = 2, legend = FALSE,
scalebar = FALSE, smooth = FALSE)

# Compare with vcgBorder from the R package Rvcg, in blue:
vcgborder <- which(Rvcg::vcgBorder(dkmodel$culp)$borderit == TRUE)
is_border[vcgborder] <- 3
dkmap(dkmodel$culp, is_border, col = c("white", "#E69F00", "#56B4E9"), col.levels = 3,
legend = FALSE, scalebar = FALSE, smooth = FALSE)
#As you can see, it all depends on what you want to select!
```

dkcrop

crop a mesh

Description

Crop a 3d triangle mesh.

Usage

```
dkcrop(mesh, y)
```

Arguments

mesh	object of class mesh3d
y	numeric vector indicating which polygons should be cropped; or an object of class polygon.network

Value

A new object of class mesh3d for which all polygons out of y have been removed.

Examples

```
#Crop above a certain threshold:
mythreshold <- quantile(elev(dkmodel$basin), 0.5)
mypolynetwork <- poly.network(dkmodel$basin, elev(dkmodel$basin),
lwr.limit = mythreshold)
mynewmesh <- dkcrop(dkmodel$basin, mypolynetwork)
dkmap(mynewmesh, elev(mynewmesh))

#Crop the sharpest dental elements:
sharpmesh <- dkcrop(dkmodel$basin, poly.network(dkmodel$basin,
Rvcg::vcgCurve(dkmodel$basin)$meanitmax,
lwr.limit = quantile(Rvcg::vcgCurve(dkmodel$basin)$meanitmax, 0.8),
min.size = 50))
dkmap(sharpmesh, arc(sharpmesh), col = "arc", col.levels = 20,
min.range = -20, max.range = 20)
#Map of the sharpest elements' elevation, slope and orientation;
dkmap(sharpmesh, elev(sharpmesh), col = "elev")
dkmap(sharpmesh, slope(sharpmesh), col = "slope", col.levels = 9,
min.range = 0, max.range = 90)
dkmap(sharpmesh, orient(sharpmesh), col = "orient", col.levels = 8,
min.range = 0, max.range = 360)
```

dkmap

3d topographic map

Description

Map topographic variables on a 3d triangle mesh.

Usage

```
dkmap(
  mesh,
  y,
  alpha = 1,
  alpha.above = TRUE,
  alpha.faces = NULL,
```

```

alpha.thresh = NULL,
bg = "white",
col = "slope",
col.levels = 100,
col.main = "black",
col.lab = "black",
col.sub = "black",
col.axis = "black",
max.range = NULL,
min.range = NULL,
lit = TRUE,
cex = 2,
cex.axis = 2,
cex.main = 4,
cex.sub = 3,
cex.lab = 2,
family = "sans",
font.axis = 1,
font.lab = 2,
font.main = 3,
font.sub = 2,
main = "",
sub = "",
legend = TRUE,
legend.lab = "y",
legend.type = "stack",
windowRect = NULL,
orient = "current",
bbox = FALSE,
origin = TRUE,
scalebar = FALSE,
smooth = TRUE
)

```

Arguments

<code>mesh</code>	object of class <code>mesh3d</code>
<code>y</code>	a vector of values for each polygon of the mesh, usually a topographic variable
<code>alpha</code>	an integer between 0 and 1 corresponding to alpha value for the selected polygons (see <code>alpha.above</code> , <code>alpha.faces</code> and <code>alpha.thresh</code>)
<code>alpha.above</code>	logical, if TRUE polygons affected by alpha should have a y value above <code>alpha.thresh</code> , if FALSE their y value should be below <code>alpha.thresh</code>
<code>alpha.faces</code>	a numeric vector of indices indicating which faces affected by alpha
<code>alpha.thresh</code>	a numeric value indicating a threshold for alpha
<code>bg</code>	the color to be used for the background. Defaults to "white".
<code>col</code>	a vector of colors for texturing the polygons according to y

<code>col.levels</code>	the number of color levels
<code>col.main</code>	the color to be used for legend main titles. Defaults to "black".
<code>col.lab</code>	the color to be used for the legend labels. Defaults to "black".
<code>col.sub</code>	the color to be used for plot sub-titles. Defaults to "black".
<code>col.axis</code>	the color to be used for legend axis annotation. Defaults to "black".
<code>max.range</code>	optional; the maximal range of the scale
<code>min.range</code>	optional; the minimal range of the scale
<code>lit</code>	logical, specifying if lighting calculation should take place on geometry
<code>cex</code>	a numerical value giving the amount by which plotting text and symbols should be magnified relative to the default. This starts as 1 when a device is opened, and is reset when the layout is changed, e.g. by setting <code>mfrow</code> .
<code>cex.axis</code>	the magnification to be used for legend axis annotation relative to the current setting of <code>cex</code> .
<code>cex.main</code>	the magnification to be used for main titles relative to the current setting of <code>cex</code> .
<code>cex.sub</code>	the magnification to be used for sub-titles relative to the current setting of <code>cex</code> .
<code>cex.lab</code>	the magnification to be used for legend labels relative to the current setting of <code>cex</code> .
<code>family</code>	the name of a font family for drawing text. The maximum allowed length is 200 bytes. This name gets mapped by each graphics device to a device-specific font description. The default value is "" which means that the default device fonts will be used (and what those are should be listed on the help page for the device). Standard values are "serif", "sans" and "mono", and the Hershey font families are also available.
<code>font.axis</code>	the font to be used for axis annotation.
<code>font.lab</code>	the font to be used for the legend axis
<code>font.main</code>	the font to be used for plot main titles.
<code>font.sub</code>	the font to be used for plot sub-titles.
<code>main</code>	the main title (on top) using font, size (character expansion) and color <code>par(c("font.main", "cex.main", "col.main"))</code>
<code>sub</code>	sub-title (at bottom) using font, size and color <code>par(c("font.sub", "cex.sub", "col.sub"))</code>
<code>legend</code>	a logical indicating whether a legend should be displayed.
<code>legend.lab</code>	a label for the legend axis.
<code>legend.type</code>	a character string specifying the type of legend to be used; default is "stack", which corresponds to a stacked vertical legend; "pie" generates a pie-shaped legend and "log" generates a stacked vertical legend, but does a log transformation of the data (base: $e=\exp(1)$). The "log" is mostly useful for DNE maps.
<code>windowRect</code>	the dimensions of the rgl window (default is the current size or, if size is below 1000*800, <code>c(20, 20, 1020, 820)</code>)
<code>orient</code>	the orientation of the view. For more details, see dksetview
<code>bbox</code>	a logical, if TRUE a bounding box will be displayed around the surface object
<code>origin</code>	logical, whether to set the z of the mesh's lowermost point to zero
<code>scalebar</code>	A logical indicating whether a scalebar should be displayed
<code>smooth</code>	A logical indicating whether the color of polygons should blend with neighbor polygons for a smoother rendering

Value

An rgl window displaying the topography of a variable over a 3d mesh.

See Also

[rgl](#)

Examples

```
#Map of orientation:
orient <- orient(dkmodel$complex)
dkmap(dkmodel$complex, orient, col.levels = 8, col = "orient",
      legend.lab = "Orientation (degrees)", legend.type = "pie", min.range = 0,
      max.range = 360, orient = "occlusal")

#Map of area-relative curvature:
arc <- arc(dkmodel$complex)
dkmap(dkmodel$complex, arc, col = "arc", legend.lab = "ARC",
      min.range = -20, max.range = 20, col.levels = 15, orient = "occlusal")

#Map of Dirichlet normal energy:
dne <- dne(dkmodel$complex)
dkmap(dkmodel$complex, dne, col = "dne", legend.lab = "DNE",
      legend.type = "log", orient = "occlusal")

#Map of 3d-Area of polygons (for surface checking):
dkmap(dkmodel$complex, Rvcg::vcgArea(dkmodel$complex, perface = TRUE)$pertriangle,
      legend.lab = "3d Area (mm\u00B2)", orient = "occlusal")
```

dkmodel

dkmodel

Description

A list containing theoretical model surfaces corresponding to a flat surface, a single cusp, a shallow basin and a complex surface.

Usage

```
dkmodel
```

Format

An object of class list of length 4.

Source

<https://github.com/nialsiG/A-comparison-of-relief-estimates-used-in-3d-dental-topography>

Examples

```
Flat_surface <- dkmodel$flat
Single_cusp <- dkmodel$cusp
Shallow_basin <- dkmodel$basin
Complex_surface <- dkmodel$complex
```

dkorigin

dkorigin

Description

Sets the lowermost point of the mesh to 0 on the Z-axis

Usage

```
dkorigin(mesh)
```

Arguments

mesh object of class mesh3d

Value

An object of class mesh3d.

Examples

```
#Map of elevation before using dkorigin:
dkmap(dkpongo$OES, doolkit::elev(dkpongo$OES), col = "elev", legend.lab = "Elevation (mm)")

#Map of elevation after dkorigin:
leveled <- dkorigin(dkpongo$OES)
dkmap(leveled, doolkit::elev(leveled), col = "elev", legend.lab = "Elevation (mm)")
```

dkpongo

dkpongo

Description

A dataset containing the OES and the EDJ surfaces of a *Pongo pygmaeus* upper second molar (SMF-1117)

Usage

```
dkpongo
```

Format

An object of class `list` of length 2.

Source

https://www.morphosource.org/Detail/MediaDetail/Show/media_id/42357

Examples

```
Pongo_OES <- dkpongo$OES
Pongo_EDJ <- dkpongo$EDJ
```

dkprofile

cumulative profile, its slope and the area under its curve

Description

A function for drawing the cumulative profile of a variable, computing the area under the curve and the slope of the profile at the arithmetic mean of the variable.

Usage

```
dkprofile(
  x,
  type = "cartesian",
  xlab = paste("cumulated frequency (%)" ),
  ylab = "",
  main = "",
  col = "red",
  alpha = 1,
  size = 1,
  linetype = "solid"
)
```

Arguments

<code>x</code>	a numeric vector
<code>type</code>	a character string indicating the type of coordinates to use ("cartesian", "polar" etc.). Currently only "cartesian" is supported.
<code>xlab</code>	title of the x axis
<code>ylab</code>	title of the y axis
<code>main</code>	main title of the plot
<code>col</code>	the color of data points
<code>alpha</code>	numeric indicating the alpha value of data points
<code>size</code>	the size of data points
<code>linetype</code>	the type of line to be traced (see <code>ggplot2</code>)

Value

A list containing (1) the area under the curve of the profile, (2) the profile to be drawn, and (3) the slope of the profile at the mean of the variable.

References

[doi:10.3389/fphys.2017.00524](https://doi.org/10.3389/fphys.2017.00524)Thiery et al. (2017)

Examples

```
#Elevation (hypsothetic) profile (see Thiery et al., 2017):
dkprofile(elev(dkpongo$0ES), main = "Elevation profile - Pongo pygmaeus",
ylab = "Elevation (%)", col = "#0072B2", linetype = "solid")

#Enamel-dentine distance (pachymetric) profile:
dkprofile(oedist(dkpongo$0ES, dkpongo$EDJ),
main = "Elevation profile - Pongo pygmaeus", ylab = "Distance (%)",
col = "#F0E442", linetype = "dashed")

#Curvature (kurtometric) profile:
dkprofile(Rvcg::vcgCurve(dkpongo$0ES)$meanitmax,
main = "Curvature profile - Pongo pygmaeus", ylab = "Curvature (%)",
col = "#D55E00", linetype = "dotted")
```

dksetview

preset orientations

Description

A function to orient 3d topographical maps using preset values.

Usage

```
dksetview(orient = "occlusal")
```

Arguments

orient a character string indicating the targeted orientation (default is occlusal)

Value

sets the orientation of the 'rgl' window.

See Also

[dkmap](#)

Examples

```
inclinCusp <- inclin(dkmodel$cusp)
dkmap(dkmodel$cusp, inclinCusp, col = "inclin", min.range = 0, max.range = 180)
dksetview()
#possible orientations are "distal", "left", "occlusal", "mesial" and "right"
```

dne

Dirichlet normal energy

Description

Compute the Dirichlet normal energy.

Usage

```
dne(mesh, range = 0.999, total = FALSE)
```

Arguments

mesh	object of class mesh3d
range	an integer between 0 and 1 indicating the percentage of values to consider for the computation. Following Pampush et al. (2016) default is set to 0.999.
total	logical, should the result of the function be the total DNE.

Details

The current algorithm gives a different estimate of DNE when compared with the values obtained using the molaR package. Albeit small, this difference likely comes from different methods of border selection. The doolkit package uses the function dkborder, which accurately selects every polygon sharing a vertex (or more) with the border.

Value

If total = FALSE, a numeric vector of dne values for all the polygons of the mesh. If total = TRUE, a single DNE value, calculated as the sum of the products of polygon normal energies * polygon areas.

References

[doi:10.1002/ajpa.21489](https://doi.org/10.1002/ajpa.21489)Bunn et al. (2011)
[doi:10.1007/s1091401693260](https://doi.org/10.1007/s1091401693260)Pampush et al. (2016)

See Also

[DNE](#)
[dkborder](#)

Examples

```

dne <- dne(dkmodel$complex)
summary(dkmodel$complex)

#total DNE value corresponds to the sum of products Dne * Area:
round(sum(dne*Rvcg::vcgArea(dkmodel$complex, perface = TRUE)$pertriangle), 3)
#can be directly computed using \code{dne}:
dne(dkmodel$complex, total = TRUE)

#render on a map:
dkmap(dkmodel$complex, dne, legend.type = "log", col = "dne")

```

elev

*elevation***Description**

Compute the elevation (z component of triangle barycenter).

Usage

```
elev(mesh, origin = TRUE)
```

Arguments

mesh	object of class mesh3d
origin	logical, if TRUE the z of the mesh is adjusted so that the lowest z = 0 (see dkorigin)

Value

A numeric vector of elevation values for all the polygons of the mesh.

See Also

[inclin](#)
[rfi](#)
[slope](#)

Examples

```

elev <- elev(dkmodel$scusp)
summary(elev)

#render on a map:
dkmap(dkmodel$scusp, elev)

```

hypso

hypso

Description

Compute the maximum height, length, width and corresponding hypsodonty index (ratio of the maximum height over the maximum length)

Usage

```
hypso(mesh, origin = TRUE)
```

Arguments

mesh	object of class mesh3d
origin	logical, whether to set the z of the mesh's lowermost point to zero.

Value

A list of values for hypsodonty index, height, length and width of the mesh. The hypsodonty index is not expressed relative to 100 but to 1. Note: the tooth surface is expected to be oriented such as the X-axis is the bucco-lingual axis, the Y-axis is the mesio-distal axis, and the occlusal plane is parallel to the (XY) plane and faces upward.

Examples

```
hypso(dkmodel$cuspid)
```

inclin

inclin

Description

Compute inclination i.e. the angle between triangles and the vertical plane in degrees, comprised between 0 and 180.

Usage

```
inclin(mesh)
```

Arguments

mesh	object of class mesh3d
------	------------------------

Value

A numeric vector of inclination values for all the polygons of the mesh.

References

[doi:10.1371/journal.pone.0066142](https://doi.org/10.1371/journal.pone.0066142) Guy et al. (2013)

See Also

[slope](#)

Examples

```
inclin <- inclin(dkmodel$culp)
summary(inclin)

#render on a map:
dkmap(dkmodel$culp, inclin, col = "inclin",
min.range = 0, max.range = 180, legend = TRUE)
```

oedist

Distance from outer enamel surface to enamel dentine junction

Description

Compute the distance from enamel vertices to dentine mesh.

Usage

```
oedist(oes, edj, ray = FALSE)
```

Arguments

oes	object of class mesh3d; should be the outer enamel surface
edj	object of class mesh3d; should be the enamel-dentine junction
ray	logical, if TRUE the search is along vertex normals (default is FALSE)

Value

A numeric vector of vertex-to-mesh distance values for all the polygons of the x mesh.

References

[doi:10.1371/journal.pone.0066142](https://doi.org/10.1371/journal.pone.0066142) Guy et al. (2013)

[doi:10.1371/journal.pone.0138802](https://doi.org/10.1371/journal.pone.0138802) Guy et al. (2015)

[doi:10.3389/fphys.2017.00524](https://doi.org/10.3389/fphys.2017.00524) Thiery et al. (2017)

[doi:10.1098/rsbl.2019.0671](https://doi.org/10.1098/rsbl.2019.0671) Schwartz et al. (2020)

See Also

[meshDist](#)

Examples

```
edd <- oedist(dkmodel$scusp, dkmodel$flat)
summary(edd)
AETgeom <- mean(edd)
#Geometric relative enamel thickness, obtained by dividing AETgeom by the
#square root of EDJ area
#Note: it is different from classic RET which requires the volume of the
#dentine inside the enamel cap (see Thiery et al., 2017)
AETgeom/sqrt(Rvcg::vcgArea(dkmodel$flat))
#Absolute crown strength:
edj_radius <- max(dist(cbind(dkmodel$flat$vb[1,], dkmodel$flat$vb[2,]))) / 2
sqrt(mean(edd) * edj_radius)

#render on a map:
oedist <- doolkit::oedist(dkmodel$scusp, dkmodel$flat)
dkmap(dkmodel$scusp, oedist)
#distance map can also be rendered on EDJ surface:
eodist <- oedist(dkmodel$flat, dkmodel$scusp)
dkmap(dkmodel$flat, eodist)
```

opc

orientation patch count

Description

Count the number of orientation patches using [poly.network](#).

Usage

```
opc(mesh, bins = 8, min.size = 3, rotation = 0)
```

Arguments

mesh	object of class mesh3d
bins	the number of orientation bins to be defined (default set to 8)
min.size	the minimal amount of polygons defining a "patch" (default set to 3)
rotation	if applicable, the number of degrees to which bins are to be rotated. By default the bins start from an angle of $\pi/2$ and rotates clockwise.

Value

A data.frame displaying the number of patches and their size (number of triangles) for each orientation bin. Note: if you want the surface area of each patch, see [poly.network](#)

References

[doi:10.1038/nature05433](https://doi.org/10.1038/nature05433) Evans et al. (2007)

See Also

[orient](#)
[opcr](#)

Examples

```
#8 bins (default):
opc <- opc(dkmodel$complex)
#8 bins starting from mesial, as in Evans et al. 2007:
opc <- opc(dkmodel$complex, rotation = -(360/16))
#4 bins (mesial, buccal, distal and lingual):
opc <- opc(dkmodel$complex, bins = 4, rotation = -(360/8))
```

opcr	<i>orientation patch count rotated</i>
------	--

Description

Compute the orientation patch count rotated of a triangle mesh.

Usage

```
opcr(mesh, bins = 8, min.size = 3)
```

Arguments

mesh	object of class mesh3d
bins	the number of orientation bins to be defined (default set to 8)
min.size	the minimal amount of polygons defining a "patch" (default set to 3)

Value

A data.frame displaying the number of patches and their size (number of triangles) for each orientation bin.

References

[doi:10.1038/nature10880](https://doi.org/10.1038/nature10880)Wilson et al. (2012)

See Also

[opc](#)
[orient](#)
[OPCr](#)

Examples

```
#8bins (default):
opcr <- opcr(dkmodel$complex)
#16 bins (computation time increase exponentially):
opcr <- opcr(dkmodel$complex, bins = 16)
```

orient	<i>orientation of polygons</i>
--------	--------------------------------

Description

Returns the occlusal orientation (exposure in GIS)

Usage

```
orient(mesh)
```

Arguments

mesh	object of class mesh3d
------	------------------------

Value

A numeric vector of occlusal orientation values in degrees for all the polygons of the mesh. Let the orientation from above be depicted as a trigonomical circle, then for a tooth positioned as in Guy et al. (2015) an orientation of 0 (mesial) would be located at an angle of $\pi/2$, and an orientation of 90° (buccal) would be located at an angle of 2π .

See Also

[opc](#)

[opcr](#)

Examples

```
orient <- orient(dkmodel$complex)
summary(orient)
```

poly.network	<i>Identify polygon networks</i>
--------------	----------------------------------

Description

From a selected variable *y*, identifies patches of adjacent polygons that share a given range of *y* values. These patches are called 'polygon networks'.

Usage

```
poly.network(
  mesh,
  y,
  lwr.limit = stats::quantile(y, 0.75),
  upr.limit = stats::quantile(y, 1),
  min.size = 3
)
```

Arguments

<code>mesh</code>	object of class <code>mesh3d</code>
<code>y</code>	a vector of indices to be used to select polygons
<code>lwr.limit</code>	the lower range of values to be selected from <i>y</i>
<code>upr.limit</code>	the upper range of values to be selected from <i>y</i>
<code>min.size</code>	the minimum amount of polygons defining a cluster. Default is set to 3.

Value

An object of class "`poly.network`" composed of the face index and the membership of each triangle answering the set conditions. The function makes patches of contiguous triangles, and each patch is indexed with a unique number corresponding to its membership.

Examples

```
#Isolate cusps using elevation:
mythreshold <- quantile(elev(dkmodel$culp), 0.65)
cusps <- poly.network(dkmodel$culp, elev(dkmodel$culp), lwr.limit = mythreshold,
min.size = 100)
myvector <- rep(0, Rvcg::nfaces(dkmodel$culp))
myvector[cusps@faces] <- cusps@membership[]
myvector <- as.factor(myvector)
ncusps <- length(levels(myvector)) - 1
levels(myvector) <- c(0:ncusps + 1)
dkmap(dkmodel$culp, as.numeric(myvector), col = cbPalette <- c("#000000", "#E69F00",
"#56B4E9", "#009E73", "#F0E442", "#0072B2", "#D55E00", "#CC79A7"),
col.levels = ncusps + 1, legend.lab = "Elevation (mm)")
```

```

#Any other variables could be used to define the clusters
#Mean curvature:
crests <- poly.network(dkmodel$complex, Rvcg::vcgCurve(dkmodel$complex)$meanitmax,
lwr.limit = quantile(Rvcg::vcgCurve(dkmodel$complex)$meanitmax, 0.8), min.size = 10)
doolkit::dkmap(mesh = dkmodel$complex, y = doolkit::arc(dkmodel$complex,
range = c(-20, 20)), col = "arc", col.levels = 256, min.range = -20,
max.range = 20, orient = "occlusal", legend.lab = "ARC",
alpha.thresh = quantile(doolkit::arc(dkmodel$complex), 0.8), alpha = 0.3,
alpha.above = FALSE)

#Orientation and surface of patches:
patch_orient <- data.frame(bin = NULL, patch = NULL, size = NULL, surface = NULL)
for (i in 1:8) {
  Cluster <- poly.network(dkmodel$complex, orient(dkmodel$complex),
lwr.limit = 45 * (i - 1), upr.limit = 45 * i)
  Patches <- levels(as.factor(Cluster@membership))
  Bins <- rep(paste(45 * (i - 1), "-", 45 * i), length(Patches))
  Areas <- rep(0, length(Patches))
  for (j in 1:length(Patches)) {
    test <- Cluster@faces[Cluster@membership == Patches[j]]
    Areas[j] <- round(sum(Rvcg::vcgArea(dkmodel$complex,
perface = TRUE)$pertriangle[test]), 3)
  }
  patch_orient <- data.frame(rbind(patch_orient,
cbind.data.frame(Bins, Patches, Areas)))
}
#Since patches made of 3 or less polygons are discarded,
#sum of patch areas < total surface area:
sum(patch_orient$Areas)
Rvcg::vcgArea(dkmodel$complex)

```

`polygon.network-class` *S4 class for polygon networks*

Description

Polygon networks are subgraphs made of polygons (i) sharing topographic features and (ii) in contact with the rest of the subgraph by at least 1 polygon edge. Objects of S4 class `polygon.network` are typically made using the function [poly.network](#)

Slots

`membership` a vector of numeric values specifying, for each triangle, the index number of the patch to which the triangle is assigned

`faces` a vector of numeric values indicating the mesh triangle indexes

rfi	<i>relief index</i>
-----	---------------------

Description

Compute the relief index of a 3d triangle mesh.

Usage

```
rfi(mesh, method = "Ungar", hull = "concave")
```

Arguments

mesh	object of class mesh3d
method	a character string indicating which method is to be used for the computation of relief index
hull	the method used to compute the hull of the 2d projection, either 'convex' or 'concave'. The default method is 'convex'. See area2d

Details

As of version 1.42.2, the concave hull fails intermittently on Mac systems, so the function defaults to convex hulls (on other systems, it defaults to concave hulls).

Value

A single relief index value.

References

[doi:10.1016/j.jhevol.2008.08.002](#)Boyer (2008) [doi:10.1371/journal.pone.0066142](#)Guy et al. (2013)
[Ungar and Williamson \(2000\)](#)

See Also

[area2d](#)

[RFI](#)

Examples

```
rfi <- rfi(dkmodel$culp, method = "Ungar", hull = "convex")
lrifi <- rfi(dkmodel$culp, method = "Boyer", hull = "convex")
gamma <- rfi(dkmodel$culp, method = "Guy")
```

rrate	<i>relief rate</i>
-------	--------------------

Description

Compute the relief rate from a sub-sample of a 3d triangle mesh. For instance, the relief rate could be computed from the portion of a molar above the lowermost point of its central basin, compared to the whole tooth.

Usage

```
rrate(uncropped, cropped, origin = TRUE)
```

Arguments

uncropped	object of class mesh3d. Should entirely contain the 'cropped' argument.
cropped	object of class mesh3d. Should be part of the 'uncropped' argument.
origin	logical, if TRUE both cropped and uncropped mesh are translated along the z-axis so that the lowest z of the uncropped mesh = 0; see dkorigin

Value

A single relief rate value.

References

[doi:10.1002/ajpa.23916](https://doi.org/10.1002/ajpa.23916)Thiery et al. (2019)

Examples

```
medelev <- median(elev(dkmodel$culp))
basins <- dkcrop(dkmodel$culp, which(elev(dkmodel$culp) < medelev))
cusps <- dkcrop(dkmodel$culp, which(elev(dkmodel$culp) > medelev))

rrate(dkmodel$culp, basins)
rrate(dkmodel$culp, cusps)
```

shape.index	<i>shape.index</i>
-------------	--------------------

Description

Compute various shape indices.

Usage

```
shape.index(mesh, origin = TRUE)
```

Arguments

mesh	object of class mesh3d
origin	logical, if TRUE the z of the mesh is adjusted so that the lowest z = 0; see dkorigin

Details

A handful of indices have been developed to characterize the shape of natural landscapes, including drainage basins. While some indices are very scale-sensitive (e.g., Gravelius' compactness coefficient), others are dimensionless. Horton (1932) introduced a form factor computed as the quotient of the basin's surface area over the square of the maximum basin length. Schumm (1956) developed a basin elongation index computed as the quotient of twice the square root of surface area over the product of basin length and the squareroot of pi. Lastly, Chorley et al. (1957) developed a lemniscate ratio which corresponds to the ratio between the surface of a lemniscate of same length over the basin area, and computed as $(\pi * (\text{Length}^2)) / (4 * \text{Area})$.

Value

A list of indices:

- Form factor (Horton, 1932)
- Basin elongation (Schum, 1956)
- Lemniscate ratio 'K' (Chorley et al., 1957)

References

[doi:10.1029/TR013i001p00350](#)Horton (1932)
[doi:10.1130/00167606\(1956\)67\[597:EODSAS\]2.0.CO;2](#)Schumm (1956)
[doi:10.2475/ajs.255.2.138](#)Chorley et al. (1957)

Examples

```
ShapInd <- shape.index(dkmodel$basin)
ShapInd$FormFactor
ShapInd$Elongation
ShapInd$K
```

`slope`

*slope***Description**

Compute slope i.e. the angle between triangles and the horizontal plane in degrees, comprised between 0 and 90.

Usage

```
slope(mesh)
```

Arguments

`mesh` object of class `mesh3d`

Value

A numeric vector of slope values for all the polygons of the mesh.

References

[Ungar and Williamson \(2000\)](#)

See Also

[inclin](#)

Examples

```
slope <- slope(dkmodel$culp)
summary(slope)

#render on a map:
dkmap(dkmodel$culp, slope, col.levels = 9, col = "slope",
min.range = 0, max.range = 90, legend = TRUE)
```

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