Package ‘geodiv’

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Type Package

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### calculate_met_focal

**Calculate Texture Metric for Single Pixel**

Calculates the various texture metrics over a window centered on an individual pixel. This function is modified slightly from the `calculate_lsm_focal` function in the `landscapemetrics` package (Hesselbarth et al. 2019).

#### Usage

```
calculate_met_focal(landscape, n_row, n_col, points, what, ...)```

#### Arguments

- **landscape**: A raster or matrix.
- **n_row**: Numeric. Number of rows in focal window.
- **n_col**: Numeric. Number of columns in focal window.
- **points**: Dataframe. Coordinates and values of cells, calculated with the *landscapemetrics* `raster_to_points` function.
- **what**: Character. Metric to calculate for each window. Metrics from the geodiv package are listed below.
- **...**: Additional arguments for the metric functions. All applicable arguments will be applied to the entire list of metrics.

#### Details

Metrics from geodiv package:

1. `sa`: average surface roughness
2. `sq`: root mean square roughness
3. `s10z`: ten-point height
4. `sdq`: root mean square slope of surface, 2-point method
5. `sdq6`: root mean square slope of surface, 7-point method
6. `sdr`: surface area ratio
7. `sb1`: surface bearing index
8. `sci`: core fluid retention index
9. `ssk`: skewness
10. `sku`: kurtosis
11. `sds`: summit density
12. `sf`d`: 3d fractal dimension
13. `srw`: dominant radial wavelength, radial wavelength index, mean half wavelength
14. `std`: angle of dominating texture, texture direction index
15. `svi`: valley fluid retention index
16. `stxr`: texture aspect ratio
17. `ssc`: mean summit curvature
18. `sv`: maximum valley depth
19. `sph`: maximum peak height
20. `sk`: core roughness depth
21. `smean`: mean peak height
22. `svk`: reduced valley depth
23. `spk`: reduced peak height
24. `sc1`: correlation length
25. `sdc`: bearing area curve height interval

**Value**

The metric value over the window.

**References**

.deg2rad

Degree to Radian Conversion

Description

Converts degree value(s) to radians.

Usage

`.deg2rad(x)`

Arguments

x Numeric. Degree value(s).

Value

Numeric of degree value(s).

.maxdist

Estimate Maximum Correlation Length

Description

Internal function to calculates the maximum distances to specified autocorrelation values (e.g., 0.2) of the areal autocorrelation function (AACF). All 180 degrees from the origin of the AACF image are considered for the calculation.

Usage

`.maxdist(threshold, aacfimg, distimg)`

Arguments

threshold A number with a value between 0 and 1. Indicates the autocorrelation value to which the rates of decline are measured.
aacfimg A raster of the areal autocorrelation function. This is the AACF raster split in two in terms of height.
distimg A raster of distances to all pixels from the center of the original image. Distances are in meters if original raster was unprojected, and are in map units (usually meters) if raster was projected (see raster::distance documentation for more details).
.mindist

Estimate Minimum Correlation Length

**Description**

Internal function to calculates the minimum distances to specified autocorrelation values (e.g., 0.2) of the areal autocorrelation function (AACF). All 180 degrees from the origin of the AACF image are considered for the calculation.

**Usage**

```
.mindist(threshold, aacfimg, distimg)
```

**Arguments**

- **threshold**
  A number with a value between 0 and 1. Indicates the autocorrelation value to which the rates of decline are measured.

- **aacfimg**
  A raster of the areal autocorrelation function. This is the AACF raster split in two in terms of height.

- **distimg**
  A raster of distances to all pixels from the center of the original image. Distances are in meters if original raster was unprojected, and are in map units (usually meters) if raster was projected (see raster::distance documentation for more details).

**Value**

A list containing the minimum distances from an autocorrelation value of 1 to the specified autocorrelation value < 1. Distances are meters if original raster was unprojected, and are in map units (usually meters) if raster was projected (see raster::distance documentation for more details).
.rad2deg  

### Radian to Degree Conversion

**Description**

Converts radian value(s) to degrees.

**Usage**

```
.rad2deg(x)
```

**Arguments**

- `x`  
  Numeric. Radian value(s).

**Value**

Numeric of degree value(s).

---

.aacf  

### Estimate the Areal Autocorrelation Function

**Description**

Calculates the areal autocorrelation function (AACF) as the inverse of the Fourier power spectrum.  
`.aacf(x)` returns the AACF in both matrix and raster format.

**Usage**

```
aacf(x)
```

**Arguments**

- `x`  
  An n x n raster or matrix.

**Value**

A raster or matrix representation of the AACF. Both raster and matrix values are normalized so that the maximum is equal to 1.
Examples

```r
library(raster)

# import raster image
data(normforest)

# calculate aacf img and matrix
aacf_out <- aacf(normforest)

# plot resulting aacf image
plot(aacf_out)
```

---

**area_above**

*Area Above the Bearing Area Curve*

**Description**

Calculates the area above the bearing area curve from points a to b. If a box is drawn around a function with the upper-left at a and the bottom-right at b, this function extracts the area above the function within the box.

**Usage**

```r
area_above(f, a, b, n = 100)
```

**Arguments**

- `f` The function for the Bearing Area curve produced by `stats::ecdf()`.
- `a` Numeric. The left x boundary.
- `b` Numeric. The right x boundary.
- `n` Numeric. The number of subdivisions along the function line.

**Details**

The area under the curve used to calculate area above the curve is calculated as the numerical integral of the Bearing Area function from a to b using the trapezoid rule with n subdivisions. Assume a < b and n is a positive integer.

**Value**

A numeric value representing the area above the curve with x bounds a and b.
Examples

library(raster)

# import raster image
data(normforest)

# basic values
z <- getValues(normforest)

# calculate cumulative probability density function of surface 'height' (= ndvi)
mod <- ecdf((1 - z))

# valley fluid retention index = void volume in 'valley' zone
Svi <- area_above(f = mod, b = 1, a = 0.8, n = 500)

bearing_area

Calculates the Rotated Bearing Area Curve

Description

Finds a rotated version of the Bearing Area (Abbott-Firestone) curve from a raster or matrix. The resulting function should be rotated 90 degrees clockwise to get the actual Bearing Area curve.

Usage

bearing_area(x)

Arguments

x

A raster or matrix.

Value

A function describing the rotated Bearing Area curve.

Examples

# import raster image
data(normforest)

# find the rotated Bearing Area curve.
ba_func <- bearing_area(normforest)

# rotate the values and re-plot
xval <- environment(ba_func)$y
yval <- (1 - environment(ba_func)$x)
plot(yval ~ xval)
**Description**

Finds the best fit polynomial surface for a raster or matrix. This function tests least squares polynomial fits with orders of 0 - 3 and determines which order minimizes the error when the fit is subtracted from the original image.

**Usage**

```r
bestfitplane(x)
```

**Arguments**

- `x` A raster or matrix.

**Value**

A raster or matrix of the same size as the input with values predicted from the best polynomial fit.

**Examples**

```r
library(raster)

# import raster image
data(orforest)

# find the least squares polynomial surface
poly <- bestfitplane(orforest)

# plot the fit
plot(poly)
```

---

**Description**

This function serves to shift the zero-frequency component of the Fourier transform to the center of the matrix.

**Usage**

```r
fftshift(x, dim = -1)
```
**findpeaks**

**Arguments**

- **x**: An n x n Fourier transform matrix.
- **dim**: Which dimension to shift the matrix. -1 swaps up/down and left/right. 1 swaps up/down. 2 swaps left/right.

**Value**

An n x n matrix with the zero-frequency component of the Fourier transform in the center.

**References**

#' This function was created from code posted by rayryeng at: https://stackoverflow.com/questions/38230794/how-to-write-fftshift-and-ifftshift-in-r.

**Examples**

```r
library(raster)

# import raster image
data(normforest)

# convert to matrix form
M <- ncol(normforest)
N <- nrow(normforest)
zmat <- matrix(raster::getValues(normforest), ncol = M, nrow = N, byrow = TRUE)

# calculate fourier transform and shift
ftmat <- fft(zmat)
ftshift <- fftshift(ftmat)

# plot real component
r <- setValues(normforest, Re(ftshift))
plot(r)
```

---

**findpeaks**

*Find Local Peaks*

**Description**

Locates local peaks on a raster or matrix. A peak is defined as any pixel where all 8 surrounding pixels have lower values, and the center pixel has a positive value.

**Usage**

`findpeaks(x)`

**Arguments**

- **x**: A raster or matrix.
Value

A dataframe of local peak locations \((x, y)\) and values \((val)\). The raster or matrix location index \((ind)\), row \((\text{row})\), and column \((\text{col})\) are also listed.

Examples

```r
# import raster image
data(normforest)

# locate peaks
peaks <- findpeaks(normforest)

# calculate the summit density (# peaks/area)
N <- ncol(normforest)
M <- nrow(normforest)
Sds <- nrow(peaks) / ((N - 1) * (M - 1))
```

findvalleys

Find Local Valleys

Description

Locates local valleys on a raster or matrix. A valley is defined as any pixel where all 8 surrounding pixels have higher values, and the center pixel has a negative value.

Usage

`findvalleys(x)`

Arguments

- `x` A raster or matrix.

Value

A dataframe of local valley locations \((x, y)\) and values \((val)\). The raster or matrix location index \((ind)\), row \((\text{row})\), and column \((\text{col})\) are also listed.

Examples

```r
# import raster image
data(normforest)

# locate peaks and valleys
peaks <- findpeaks(normforest)
valleys <- findvalleys(normforest)

# find top 5 peaks, valleys
top_peaks <- peaks[order(peaks$val, decreasing = TRUE)[1:5],]
```
find_flat

bottom_valleys <- valleys[order(valleys$val)[1:5],]

# calculate the ten-point height
S10z <- (sum(top_peaks$val) + sum(abs(bottom_valleys$val))) / 5

---

find_flat  

Finds the Flattest Part of the Bearing Area Curve

Description

Locates the flattest x percentage of the Bearing Area curve. Meant to locate the flattest 40 percent of the Bearing Area curve as used in several roughness parameter calculations.

Usage

find_flat(x, perc = 0.4)

Arguments

x  
A raster or matrix.

perc  
Numeric between 0 and 1. The percentage of the curve over which to fit the line.

Value

A list containing the equation for the best fit line, the predicted values from that line, the high and low y-intercept values for the intersection points of the line with the Bearing Area curve, and the high and low x-intercept values for the intersection points of the line with the Bearing Area curve.

Examples

# import raster image
data(normforest)

# locate the flattest 40% of the bearing area curve
line_data <- find_flat(normforest, perc = 0.4)

# extract the equation of the line
bf_line <- line_data[[1]]
fitplane  
*Calculate a Least Squares Polynomial Surface*

**Description**

Fits a polynomial surface of order \( n \) to a raster or matrix.

**Usage**

```r
fitplane(x, order)
```

**Arguments**

- **x**: A raster or matrix.
- **order**: Numeric. Indicates the polynomial order to be fit.

**Value**

A matrix with values predicted from the polynomial fit.

**Examples**

```r
library(raster)

# import raster image
data(orforest)

# find the 2nd order least squares polynomial surface
polyfit <- fitplane(orforest, order = 2)

# create raster of polyfit
x <- setValues(orforest, polyfit)

# plot the fit
plot(x)
```

flatsa  
*Flattened Surface Area*

**Description**

Calculates the surface area of a flat raster or matrix with the same x, y bounds as the study surface.

**Usage**

```r
flatsa(x)
```
Arguments

x A raster or matrix.

Details

This function scales both x and y to between 0 and 1. This is done because most satellite data have units where the x, y units do not equal the z units and because the flat surface area is usually compared to the actual surface area. Surface area is calculated over the sample area (N-1, M-1).

Value

A numeric value representing the scaled surface area of a flattened surface with the same x, y bounds.

Examples

# import raster image
data(normforest)

# calculate flattened surface area
flatsa(normforest)

focal_metrics Calculate Texture Metrics per Pixel

Description

Calculates the various texture metrics over windows centered on individual pixels. This creates a continuous surface of the texture metric. This function is a modified version of the window_lsm function from the landscapemetrics package (Hesselbarth et al. 2019).

Usage

focal_metrics(x, window, metrics, progress, ...)

Arguments

x A raster or matrix. Image over which to apply focal window calculations.

window Matrix. The focal window used to create the image.

metrics List. List of metrics to apply. Function names must be strings.

progress Logical. Display progress through metrics list?

... Additional arguments for the metric functions. All applicable arguments will be applied to the entire list of metrics.
Details

Metrics available from geodiv package:

1. 'sa': average surface roughness
2. 'sq': root mean square roughness
3. 's10z': ten-point height
4. 'sdq': root mean square slope of surface, 2-point method
5. 'sdq6': root mean square slope of surface, 7-point method
6. 'sdr': surface area ratio
7. 'sbi': surface bearing index
8. 'sci': core fluid retention index
9. 'ssk': skewness
10. 'sku': kurtosis
11. 'sds': summit density
12. 'sfld': 3d fractal dimension
13. 'srw': dominant radial wavelength, radial wavelength index, mean half wavelength
14. 'std': angle of dominating texture, texture direction index
15. 'svi': valley fluid retention index
16. 'stxr': texture aspect ratio
17. 'ssc': mean summit curvature
18. 'sv': maximum valley depth
19. 'sph': maximum peak height
20. 'sk': core roughness depth
21. 'smean': mean peak height
22. 'svk': reduced valley depth
23. 'spk': reduced peak height
24. 'sc1': correlation length
25. 'sdc': bearing area curve height interval

Value

A raster of the metric calculated in windows over the raster or matrix. If the input was a matrix, the function will return a raster with an extent of [0, 1, 0, 1].

References

height_ba

Examples

```r
library(raster)

# import raster image
data(normforest)

# crop raster to smaller area
x <- crop(normforest, extent(normforest, 1, 100, 1, 100))

# get a surface of root mean square roughness
sa_img <- focal_metrics(x = x, window = matrix(1, 5, 5),
                           metrics = list('sa'), progress = TRUE)

# plot the result
plot(sa_img$sa)
```

---

### height_ba

**Value of the Bearing Area Curve at a Specified Value**

**Description**

Determines the value of the bearing area curve for a specific value along the x-axis (xval).

**Usage**

```r
height_ba(x, xval)
```

**Arguments**

- `x` A raster or matrix.
- `xval` Numeric value along the x-axis.

**Value**

A numeric value of the bearing area function corresponding to xval.

**Examples**

```r
# import raster image
data(normforest)

# determine the bearing area function value
# corresponding to an x value of 0.4
val <- height_ba(normforest, 0.4)
```
Description

A raster image of Normalized Difference Vegetation Index (NDVI) errors derived from Landsat data for a small portion of SW Oregon state. This raster was calculated by subtracting the best-fit polynomial plane from the orforest values. The best-fit polynomial plane was calculated using bestfitplane.

Usage

normforest

Format

A raster image with 371 x 371 pixels

range -0.5854638 – 0.1585918
bounds -123, -122.9, 43.0002, 43.1
resolution 30m x 30m (0.002694946 degrees)
projection WGS84
scalar 1 ...

Details

NDVI values are derived from Landsat scene path 45, row 30 summarized as the mean NDVI value between June and August 2000 at roughly 30m resolution. Clouds were removed from the Landsat scene before calculating the mean. The image was created using Google Earth Engine in August 2018.

Description

A raster image of Shuttle Radar Topography Mission (SRTM) elevation for a portion of southwestern Oregon.

Usage

orelevation

orelevation

SRTM elevation for a portion of southwestern Oregon, USA.
**Format**

A raster image with 371 x 371 pixels

- **range** 433 – 1390
- **bounds** -123.0001, -122.9002, 43.00015, 43.10013
- **resolution** 30m x 30m (0.002694946 degrees)
- **projection** WGS84

**Details**

Elevation values are from the SRTM data for 2000 and are at roughly 30m resolution. The image was created using Google Earth Engine in October 2019.

---

**orforest**  
*NDVI for a portion of southwestern Oregon, USA.*

**Description**

A raster image of Normalized Difference Vegetation Index (NDVI) derived from Landsat data for a small portion of SW Oregon state.

**Usage**

orforest

**Format**

A raster image with 371 x 371 pixels

- **range** 0 – 1
- **bounds** -123, -122.9, 43.0002, 43.1
- **resolution** 30m x 30m (0.002694946 degrees)
- **projection** WGS84

**Details**

NDVI values are derived from Landsat scene path 45, row 30 summarized as the mean NDVI value between June and August 2000 at roughly 30m resolution. Clouds were removed from the Landsat scene before calculating the mean. The image was created using Google Earth Engine in August 2018.
** PAD EDGES  **

*Extend edges of a matrix.*

** Description **

Extends edge values of a raster or matrix by a specified number of pixels.

** Usage **

```r
pad_edges(x, size, val = NULL)
```

** Arguments **

- `x`: A matrix.
- `size`: Numeric. Number of pixels to add to each side.
- `val`: Numeric. If NULL (default), this extends the edge values out. If not null, this value will be used for the extended cells.

** Value **

A raster with edges padded size number of pixels on each edge.

** Examples **

```r
library(raster)

# import raster image
data(normforest)

# crop raster to much smaller area
x <- pad_edges(as.matrix(normforest), 3, val = NA)
```

---

** PLOT BA CURVE  **

*Plots the Bearing Area Curve.*

** Description **

Calculates and plots the Bearing Area curve for a raster or matrix using the `bearing_area()` function (with correctly rotated results).

** Usage **

```r
plot_ba_curve(x, divisions = FALSE)
```
**remove_plane**

**Arguments**

- **x**  
  A raster or matrix.

- **divisions**  
  Logical, defaults to FALSE. If TRUE, divisions of the curve will be plotted. See details section for more information.

**Details**

If divisions = TRUE, the lines representing the best fit line to the flattest 40 percent of the curve will be shown, as well as both the x and y interception points of that line.

**Value**

Plots the Bearing Area curve.

**Examples**

```r
# import raster image
data(normforest)

# plot the bearing area curve
plot_ba_curve(normforest, divisions = TRUE)
```

---

**Description**

Finds the best fit polynomial surface for a raster or matrix and subtracts it from the actual values. The output image has positive values where the actual values are higher than the surface and negative values where the actual value are lower than the surface.

**Usage**

```r
remove_plane(x)
```

**Arguments**

- **x**  
  A raster or matrix.

**Value**

A raster or matrix of the same size as the input with values equal to the difference between the original and bestfit plane.
Examples

```r
library(raster)

# import raster image
data(orforest)

# remove the least squares polynomial surface
new_rast <- remove_plane(orforest)

# plot
plot(new_rast)
```

---

**rotate**

Rotates a matrix 180 degrees.

**Description**


**Usage**

```r
rotate(x)
```

**Arguments**

- `x` A matrix.

**Value**

A matrix rotate 180 degrees.

---

**s10z**

Ten-Point Height

**Description**

Calculates the average height above the mean surface for the five highest local maxima plus the average height below the mean surface for the five lowest local minima.

**Usage**

```r
s10z(x)
```

**Arguments**

- `x` A raster or matrix.
Value

A numeric value representing the ten-point height.

Examples

```r
# import raster image
data(normforest)

# calculate ten-point height.
S10z <- s10z(normforest)
```

---

**sa**  
*Calculated the Average Roughness of a Surface*

Description

Finds the average roughness of a surface (Sa) as the absolute deviation of surface heights from the mean surface height. Height is measured as the value of a raster and may not necessarily represent actual height.

Usage

```r
sa(x)
```

Arguments

- `x`  
  A raster or matrix.

Value

A value of average roughness in the units of the original raster or matrix.

Examples

```r
# import raster image
data(normforest)

# find the surface roughness
roughness <- sa(normforest)
```
**sbi**  
*Surface Bearing Index*

**Description**
Determines the surface bearing index (Sbi), calculated as the ratio of root mean square roughness (Sq) to height at 5% of bearing area (z05).

**Usage**
sbi(x)

**Arguments**

x  
A raster or matrix.

**Value**
A numeric value representing the surface bearing index.

**Examples**

```r
# import raster image
data(normforest)

data(normforest)

# determine the surface bearing index
Sbi <- sbi(normforest)
```

---

**sci**  
*Core Fluid Retention Index*

**Description**
Determine the core fluid retention index (Sci). This value is the void volume (area under the bearing area curve) in the 'core' zone. See Figure 2a from Kedron et al. (2018) for more details.

**Usage**

sci(x)

**Arguments**

x  
A raster or matrix.

**Value**
A numeric value representing the core fluid retention index.
Examples

# import raster image
data(normforest)

# determine the core fluid retention index
Sci <- sci(normforest)

scl

Calculate Correlation Length

Description

Calculates the smallest and largest distances to specified autocorrelation values (e.g., 0.2) of the areal autocorrelation function (AACF). All 180 degrees from the origin of the AACF image are considered for the calculation.

Usage

scl(x, threshold = c(0.2, 1/exp(1)), create_plot = FALSE)

Arguments

x A raster or matrix.
threshold A numeric vector containing values between 0 and 1. Indicates the autocorrelation values to which the rates of decline are measured.
create_plot Logical. Defaults to FALSE. If TRUE, the AACF and lines showing the considered directions of autocorrelation from the origin will be plotted.

Value

A list containing the minimum and maximum distances from an autocorrelation value of 1 to the specified autocorrelation values < 1. Distances are in the units of the x, y coordinates of the raster image. If more than one threshold value is specified, the order of this list will be [minval(t1), minval(t2), maxval(t1), maxval(t2)].

Examples

library(raster)

# import raster image
data(normforest)

# calculate Scl20, the minimum distance to an autocorrelation value of 0.2 in the AACF
Scl20 <- scl(normforest)[1]
sdc  

*Height Intervals of the Bearing Area Curve*

**Description**

Determines the height interval (height distance) for points along the bearing area curve as defined by their x values.

**Usage**

\[
\text{sdc}(x, \text{low}, \text{high})
\]

**Arguments**

- **x**  
  A raster or matrix.

- **low**  
  Numeric value along the x-axis corresponding to the lowest value of interest along the x-axis.

- **high**  
  Numeric value along the y-axis corresponding to the highest value of interest along the x-axis.

**Value**

A numeric value of the difference in height of the y values along the bearing area curve corresponding to the specified x values.

**Examples**

```r
# import raster image
data(normforest)

# determine the 10-40% height interval of the
# bearing area curve
val <- sdc(normforest, 0.1, 0.4)
```

---

sdq  

*Root Mean Square Slope of Surface*

**Description**

Calculates the root mean square slope of a raster or matrix surface using the two-point method.

**Usage**

\[
\text{sdq}(x)
\]
**sdq6**

**Arguments**

x  
A raster or matrix.

**Value**

A numeric value representing the two-point root mean square slope, Sdq. The units of the returned value are change in z per one unit (pixel).

**References**

This function is based on the equations found at https://www.ntmdt-si.ru/data/media/files/manuals/image_analisys_p9_nov12.e.pdf.

**Examples**

```r
# import raster image
data(normforest)

# calculate root mean square slope
Sdq <- sdq(normforest)
```

---

### sdq6  
**Root Area Mean Square Slope of Surface**

**Description**

Calculates the area root mean square slope of a raster or matrix surface using the seven-point method.

**Usage**

sdq6(x)

**Arguments**

x  
A raster or matrix.

**Value**

A numeric value representing the seven-point root mean square slope, Sdq6. The units of the returned value are change in z per one unit (pixel).

**References**

This function is based on the equations found at https://www.ntmdt-si.ru/data/media/files/manuals/image_analisys_p9_nov12.e.pdf.
sdr

Examples

```r
# import raster image
data(normforest)

# calculate area root mean square slope
Sdq6 <- sdq6(normforest)
```

---

**sdr**

**Surface Area Ratio**

---

**Description**

Calculates the surface area ratio of a raster or matrix. This is the ratio of a flat surface to the actual surface.

**Usage**

```r
sdr(x)
```

**Arguments**

- `x`: A raster or matrix.

**Details**

This function scales both x and y, as well as the surface value (z), to between 0 and 1 to best match their units. This is done because most satellite data have units where the x, y units do not equal the z units. Surface area is calculated over the sample area (N-1, M-1).

**Value**

A numeric value representing the surface area ratio.

**Examples**

```r
# import raster image
data(normforest)

# calculate the surface area ratio
Sdr <- sdr(normforest)
```
**sds**  
*Summit Density*

**Description**
Calculates the summit density of a raster or matrix. Summit density is the number of local peaks per unit area.

**Usage**
`sds(x)`

**Arguments**

- **x**: A raster or matrix.

**Value**
A numeric value representing the summit density.

**Examples**

```r
# import raster image
data(normforest)

# calculate summit density.
Sds <- sds(normforest)
```

**sfd**  
*Calculate the fractal dimension of a raster.*

**Description**
Calculates the 3D fractal dimension of a raster using the triangular prism surface area method.

**Usage**
`sfd(x, silent = FALSE)`

**Arguments**

- **x**: A raster or matrix.
- **silent**: Logical. If FALSE (default), the function will print warning messages.

**Value**
A numeric value representing the fractal dimension of the image.
References


Examples

# import raster image
data(normforest)

# calculate the fractal dimension
Sfd <- sfd(normforest)

Description

Calculates the 3D fractal dimension of a raster using the triangular prism surface area method.

Usage

sfd_(mat)

Arguments

mat A matrix.

Value

A numeric value representing the fractal dimension of the image.

References


Examples

# import raster image
data(normforest)

# convert to matrix
mat <- raster::as.matrix(normforest)

# calculate the fractal dimension
Sfd <- sfd_(mat)
simpsons

Simpson’s Rule Empirical Area Under a Curve

Description

Calculates the area below a curve from points a to b. This function is provided for general use.

Usage

simpsons(f, a, b, n = 100)

Arguments

- **f**: A function.
- **a**: Numeric. The left x boundary.
- **b**: Numeric. The right x boundary.
- **n**: Numeric. The number of subdivisions along the function line.

Details

Note that if y-values are negative, this returns the area above the function line.

Value

A numeric value representing the area under the curve with x bounds a and b.

Examples

library(raster)

# import raster image
data(normforest)

# basic values
z <- getValues(normforest)

# calculate cumulative probability density function of surface 'height' (= ndvi)
mod <- ecdf((1 - z))

# calculate integral
int_area <- simpsons(f = mod, b = 1, a = 0.8, n = 500)
Core Roughness Depth

**Description**

Determines the core roughness depth (Sk), the height difference between y values of the intersection points of the least mean square line fit to the flattest 40% of the bearing area curve. See Figure 2a from Kedron et al. (2018) for more details.

**Usage**

```r
sk(x)
```

**Arguments**

- `x`: A raster.

**Value**

A numeric value representing the core roughness depth of the image.

**Examples**

```r
# import raster image
data(normforest)

# determine the core roughness depth
Sk <- sk(normforest)
```

Calculates the Kurtosis of Raster Values

**Description**

Finds the kurtosis for a distribution of raster or matrix values (Sku). Kurtosis represents the peakedness of the raster surface height distribution. Height is measured as the value of a raster/matrix and may not necessarily represent actual height.

**Usage**

```r
sku(x, excess = TRUE)
```

**Arguments**

- `x`: A raster or matrix.
- `excess`: Logical, defaults to `TRUE`. If `TRUE`, excess kurtosis is calculated. If `FALSE`, kurtosis is calculated as the difference from the normal distribution.
Value

A numeric value representing kurtosis.

Examples

```r
# import raster image
data(normforest)

# find the excess kurtosis of the raster distribution
Sku <- sku(normforest, excess = TRUE)
```

---

**slopecalc**

*Determines the Slopes Along the Bearing Area Curve*

Description

Calculates the slopes along the bearing area curve of a raster or matrix. Slopes are determined at points \(x\), from point \(x - h\) to \(x + h\).

Usage

`slopecalc(x, h, f)`

Arguments

- **x**: A vector of \(x\) values.
- **h**: Spacing before and after each point. \(2h\) is the distance over which slopes are calculated.
- **f**: Bearing area function as calculated with `bearing_area`.

Value

A dataframe with the slope for each segment with centerpoint \(x\).

Examples

```r
# import raster image
data(normforest)

# find the slopes along the bearing area curve
ba <- bearing_area(normforest)
x <- seq(0, 1, length.out = 100000)
slopes <- slopecalc(x = x, h = 0.01, f = ba)
```
slopesmeans  
*Determines the Average Slope Along Larger Segments of the Bearing Area Curve*

**Description**

Calculates the average slope over every segment of a specified percentage length of the total bearing area curve.

**Usage**

```
slopesmeans(slopes, l = 0.4)
```

**Arguments**

- **slopes**: A dataframe containing all slopes along the bearing area curve, calculated using the `slopecalc` function.
- **l**: Percentage of the curve over which to calculate mean slope.

**Value**

A dataframe with the average slope over segments beginning at specified x locations along the bearing area curve. 'slope' represents the mean slope over the segment, 'xstart' is the beginning x location of the segment, and 'xend' is the concluding x location of the segment.

**Examples**

```r
# import raster image
data(normforest)

# find the average slope of segments of the bearing area curve.
ba <- bearing_area(normforest)
x <- seq(0, 1, length.out = 10000)
slopes <- slopecalc(x = x, h = 0.01, f = ba)
slopes_forty <- slopesmeans(slopes = slopes, l = 0.4)
```

---

smean  
*Calculates the Mean Peak Height of a Surface Image*

**Description**

Finds the mean height of positive values in the landscape (mean peak height; Smean) for a raster or matrix representing a surface.
Usage
smean(x)

Arguments
x A raster or matrix.

Value
A numeric value of mean peak height.

Examples
# import raster image
data(normforest)

# find the maximum peak height
Smean <- smean(normforest)

sph

Calculates the Maximum Peak Height of a Surface Image

Description
Finds the absolute value of the highest value in the landscape (maximum peak height; Sph) for a
raster or matrix representing a surface.

Usage
sph(x)

Arguments
x A raster or matrix.

Value
A numeric value of maximum peak height.

Examples
# import raster image
data(normforest)

# find the maximum peak height
Sph <- sph(normforest)
**spk**  
*Reduced Peak Height*

**Description**
Determine the reduced peak height (Spk), the height difference between the maximum y value of the bearing area curve and the y value of the highest intersection point of the least mean square line fit to the flattest 40% of the bearing area curve. See Figure 2a from Kedron et al. (2018) for more details.

**Usage**
```
spk(x)
```

**Arguments**
- `x` A raster or matrix.

**Value**
A numeric value representing the reduced peak height.

**Examples**
```r
# import raster image
data(normforest)

# determine the reduced peak height
Spk <- spk(normforest)
```

---

**sq**  
*Calculates the Root Mean Square Roughness of a Surface*

**Description**
Finds the root mean square roughness of a surface (Sq) as the standard deviation of surface heights from the mean surface height. Height is measured as the value of a raster and may not necessarily represent actual height.

**Usage**
```
sq(x)
```

**Arguments**
- `x` A raster or matrix.
Value

A value of root mean square roughness in the units of the original raster or matrix.

Examples

```r
# import raster image
data(normforest)

# find the surface roughness
roughness <- sq(normforest)
```

---

**srw**

*Radial Wavelength Metrics*

Description

Calculates the dominant radial wavelength, radial wavelength index, and mean half wavelength of the radial Fourier spectrum. See Kedron et al. (2018) for more detailed description.

Usage

```
srw(x, create_plot = FALSE, option = c(1, 2, 3))
```

Arguments

- **x**: A raster or matrix.
- **create_plot**: Logical. If TRUE, returns a plot of the amplitude spectrum with lines showing the radii at which Srw, Srwi, and Shw are calculated.
- **option**: Numeric. Code for which output metric(s) to return. 1 = Srw, 2 = Srwi, 3 = Shw.

Value

A vector containing numeric values for the dominant radial wavelength, radial wavelength index, and mean half wavelength.

Examples

```r
library(raster)

# import raster image
data(normforest)

# calculate metrics
srwvals <- srw(normforest)

# extract each value
Srw <- srwvals[1]
Srwi <- srwvals[2]
Shw <- srwvals[3]
```
**ssc**  
*Mean Summit Curvature*

**Description**
Calculates the mean summit curvature of a raster or matrix. Mean summit curvature is the average principle curvature of local maxima on the surface.

**Usage**
```r
ssc(x)
```

**Arguments**
- `x` A raster or matrix.

**Value**
A numeric value representing the average curvature of surface peaks.

**Examples**
```r
# import raster image
data(normforest)

# calculate mean summit curvature
Ssc <- ssc(normforest)
```

---

**ssk**  
*Calculates the Skewness of Raster Values*

**Description**
Finds the Fisher-Pearson coefficient of skewness for raster or matrix values (Ssk). Skewness represents the asymmetry of the surface height distribution. Height is measured as the value of a raster/matrix and may not necessarily represent actual height.

**Usage**
```r
ssk(x, adj = TRUE)
```

**Arguments**
- `x` A raster or matrix.
- `adj` Logical, defaults to TRUE. If TRUE, the adjusted Fisher-Pearson coefficient of skewness is calculated. Otherwise, the standard coefficient is calculated.
**Value**

A numeric value representing skewness.

```r
# import raster image
data(normforest)
# find the adjusted coefficient of skewness
Ssk <- ssk(normforest, adj = TRUE)
```

---

**Description**

Calculates the angle of dominating texture and the texture direction index of the Fourier spectrum image calculated from a raster image (see Kedron et al. 2018).

**Usage**

```r
std(x, create_plot = FALSE, option = c(1, 2))
```

**Arguments**

- `x`: A raster or matrix.
- `create_plot`: Logical. If `TRUE`, returns a plot of the amplitude spectrum with lines showing directions in which amplitude is summed for the Std and Stdi calculations. Plotting is not possible when input is a matrix.
- `option`: Numeric. Code for which output metric(s) to return. 1 = Std, 2 = Stdi.

**Value**

A vector containing numeric values for the angle of dominating texture and the texture direction index.

**Examples**

```r
library(raster)

# import raster image
data(normforest)

# calculate Std and Stdi
stdvals <- std(normforest)

# extract each value
Std <- stdvals[1]
Stdi <- stdvals[2]
```
**stxr**  
*Estimate Texture Aspect Ratio*

**Description**

Calculates the texture aspect ratio (Str) at defined autocorrelation values. The texture aspect ratio is the ratio of the fastest to the slowest decay lengths of the autocorrelation function to the defined autocorrelation values.

**Usage**

```r
stxr(x, threshold = c(0.2, 1/exp(1)))
```

**Arguments**

- **x**: A raster or matrix.
- **threshold**: A vector of autocorrelation values with values between 0 and 1. Indicates the autocorrelation value(s) to which the rates of decline are measured.

**Value**

A vector with length equal to that of `threshold` containing the texture aspect ratio(s) for the input autocorrelation value(s).

**Examples**

```r
library(raster)

# import raster image
data(normforest)

# estimate the texture aspect ratio for autocorrelation thresholds of 0.20 and 0.37 (1/e)
strvals <- stxr(normforest, threshold = c(0.20, 1/exp(1)))

# calculate Str20, the texture aspect ratio for autocorrelation value of 0.2 in the AACF
Str20 <- strvals[1]
```
**surface_area**

*Surface Area*

**Description**

Calculates the scaled surface area of a raster or matrix.

**Usage**

`surface_area(x)`

**Arguments**

- `x` A raster or matrix.

**Details**

This function scales both x and y, as well as the surface value (z), to between 0 and 1 to best match their units. This is done because most satellite data have units where the x, y units do not equal the z units. The surface area represents the surface area of the sample area (N-1, M-1). Note that the surface object may have NA values around the edges, but should not have any missing values within the main area.

**Value**

A numeric value representing the scaled surface area.

**Examples**

```r
# import raster image
data(normforest)

# calculate surface area
surface_area(normforest)
```

---

**sv**

*Calculates the Maximum Valley Depth of a Surface Image*

**Description**

Finds the absolute value of the lowest value in the landscape (maximum valley depth; Sv) for a raster or matrix representing a surface.

**Usage**

`sv(x)`
**Arguments**

x  
A raster or matrix.

**Value**

A numeric value of maximum valley depth.

**Examples**

```
# import raster image
data(normforest)

# find the maximum valley depth
Sv <- sv(normforest)
```

---

**svi**  
Valley Fluid Retention Index

**Description**

Determines the valley fluid retention index (Svi). This value is the void volume (area under the bearing area curve) in the 'valley' zone. See Figure 2a from Kedron et al. (2018) for more details.

**Usage**

`svi(x)`

**Arguments**

x  
A raster or matrix.

**Value**

A numeric value representing the valley fluid retention index.

**Examples**

```
# import raster image
data(normforest)

# determine the valley fluid retention index
Svi <- svi(normforest)
```
svk  

**Reduced Valley Depth**

**Description**

Determines the reduced valley depth (Svk), the height difference between y value of the lowest intersection point of the least mean square line fit to the flattest 40% of the bearing area curve and the minimum y value of the bearing area curve. See Figure 2a from Kedron et al. (2018) for more details.

**Usage**

```r
svk(x)
```

**Arguments**

- `x` A raster or matrix.

**Value**

A numeric value representing the reduced valley depth.

**Examples**

```r
# import raster image
data(normforest)

# determine the reduced valley depth
Svk <- svk(normforest)
```

texture_image  

**Calculate Texture Metrics per Pixel**

**Description**

Calculates the various texture metrics over windows centered on individual pixels. This creates a continuous surface of the texture metric.

**Usage**

```r
texture_image(
  x,
  window_type = "square",
  size = 5,
  in_meters = FALSE,
  metric,
)```
ARGS

x
A raster or matrix.

window_type
Character. Type of window, either circular or square.

size
Numeric. Size of window (edge length) or diameter (in meters).

in_meters
Logical. Is the size given in meters?

metric
Character. Metric to calculate for each window. Metrics from the geodiv package are listed below.

args
List. Arguments from function to be applied over each window (e.g., list(threshold = 0.2)).

parallel
Logical. Option to run the calculations in parallel on available cores.

ncores
Numeric. If parallel is TRUE, number of cores on which to run the calculations. Defaults to all available, minus 1.

nclumps
Numeric. Number of clumps to split the raster or matrix into.

DETAILS

Note that this function is meant to work on rasters with an equal area projection.

Metrics available from geodiv package:

1. 'sa': average surface roughness
2. 'sq': root mean square roughness
3. 's10z': ten-point height
4. 'sdq': root mean square slope of surface, 2-point method
5. 'sdq6': root mean square slope of surface, 7-point method
6. 'sdr': surface area ratio
7. 'sbi': surface bearing index
8. 'sci': core fluid retention index
9. 'ssk': skewness
10. 'sku': kurtosis
11. 'sds': summit density
12. 'sfd': 3d fractal dimension
13. 'srw': dominant radial wavelength, radial wavelength index, mean half wavelength
14. 'std': angle of dominating texture, texture direction index
15. 'svi': valley fluid retention index
16. 'stxr': texture aspect ratio
17. 'ssc': mean summit curvature
18. 'sv': maximum valley depth
19. 'sph': maximum peak height
20. 'sk': core roughness depth
21. 'smean': mean peak height
22. 'svk': reduced valley depth
23. 'spk': reduced peak height
24. 'scl': correlation length
25. 'sdc': bearing area curve height interval

Value

A raster or list of rasters (if function results in multiple outputs) with pixel values representative of the metric value for the window surrounding that pixel.

Note

The total window size for square windows will be (size * 2) + 1.

Examples

library(raster)

# import raster image
data(normforest)

# crop raster to smaller area
x <- crop(normforest, extent(normforest, 1, 100, 1, 100))

# get a surface of root mean square roughness
sa_img <- texture_image(x = x, window = 'square', size = 5, metric = 'sa', parallel = TRUE, ncores = 2, nclumps = 20)

# plot the result
plot(sa_img)
Usage

window_metric(
  x,
  coords,
  window_type = "square",
  size = 11,
  metric,
  args = NULL
)

Arguments

x
A raster or matrix.

coords
Dataframe. Coordinates of window edges.

window_type
Character. Type of window, either circular or square.

size
Numeric. Edge length or diameter of window in number of pixels.

metric
Character. Metric to calculate for each window. Metrics from the geodiv package are listed below.

args
List. Arguments from function to be applied over each window (e.g., list(threshold = 0.2)).

Details

Metrics from geodiv package:
1. 'sa': average surface roughness
2. 'sq': root mean square roughness
3. 's10z': ten-point height
4. 'sdr': root mean square slope of surface, 2-point method
5. 'sdq6': root mean square slope of surface, 7-point method
6. 'sdr': surface area ratio
7. 'sbi': surface bearing index
8. 'sci': core fluid retention index
9. 'ssk': skewness
10. 'sku': kurtosis
11. 'sds': summit density
12. 'sfd': 3d fractal dimension
13. 'srw': dominant radial wavelength, radial wavelength index, mean half wavelength
14. 'std': angle of dominating texture, texture direction index
15. 'svi': valley fluid retention index
16. 'stxr': texture aspect ratio
17. 'ssc': mean summit curvature
18. 'sv': maximum valley depth
19. 'sph': maximum peak height
20. 'sk': core roughness depth
21. 'smean': mean peak height
22. 'svk': reduced valley depth
23. 'spk': reduced peak height
24. 'scl': correlation length
25. 'sdc': bearing area curve height interval

Value

A raster with pixel values representative of the metric value for the window surrounding that pixel.

Note

Note that if calculating the metric at the edge of a raster or matrix, the input raster/matrix must be padded. This can be done using the `pad_edges` function.

---

### zshift

**Offset Raster or Matrix Values**

**Description**

Calculates a matrix of values with a negative or positive, x or y, offset.

**Usage**

```r
zshift(r, xdist = 0, ydist = 0, xrm, yrm, scale = FALSE)
```

**Arguments**

- **r** - A raster or matrix.
- **xdist** - Numeric indicating the number and direction (+, -) of columns for the offset.
- **ydist** - Numeric indicating the number and direction (+, -) of rows for the offset.
- **xrm** - Numeric value or vector indicating the number of columns to be removed from the final matrix. If not set, this value defaults to `xdist`. Positive values remove columns from the right, while negative values remove columns from the left. The absolute value of `xrm` must be >= abs(`xdist`).
- **yrm** - Numeric value or vector indicating the number of rows to be removed from the final matrix. If not set, this value defaults to `ydist`. Positive values remove rows from the bottom, while negative values remove rows from the top. The absolute value must be >= abs(`ydist`).
- **scale** - Logical. Indicates whether or not to scale the values of the raster.
Value

A numeric vector of values created from a matrix of the values with the specified offset. The vector is created from a matrix with \( x_{rm} \) fewer columns and \( y_{rm} \) fewer rows than the original raster value matrix.

Examples

```r
# import raster image
data(normforest)

# remove right and bottom borders 2 deep
noborder <- zshift(normforest, xdist = 2, ydist = 2)
```
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