Package ‘starsExtra’

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Title  Miscellaneous Functions for Working with ‘stars’ Rasters
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Description  Miscellaneous functions for working with ‘stars’ objects, mainly single-band rasters. Currently includes functions for: (1) focal filtering, (2) detrending of Digital Elevation Models, (3) calculating flow length, (4) calculating the Convergence Index, (5) calculating topographic aspect and topographic slope.
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R topics documented:

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Calculate topographic aspect from a DEM

Description

Calculates topographic aspect given a Digital Elevation Model (DEM) raster. Input and output are rasters of class stars, single-band (i.e., only "x" and "y" dimensions), with one attribute.

Usage

aspect(x, na_flag = -9999)

Arguments

x

A raster (class stars) with two dimensions: x and y, i.e., a single-band raster, representing a DEM.

na_flag

Value used to mark NA values in C code. This should be set to a value which is guaranteed to be absent from the input raster x (default is -9999).
**Value**

A star's raster with topographic slope, i.e., the azimuth where the terrain is tilted towards, in decimal degrees (0-360) clockwise from north. Aspect of flat terrain, i.e., where all values in the neighborhood are equal, is set to -1. Returned raster values are of class units (decimal degrees).

**Note**

Aspect calculation results in NA when at least one of the cell neighbors is NA, including the outermost rows and columns. Given that the focal window size in aspect calculation is 3*3, this means that the outermost one row and one column are given an aspect value of NA.

**References**

The topographic aspect algorithm is based on the *How aspect works* article in the ArcGIS documentation:


**Examples**

```r
# Small example
data(dem)
dem_aspect = aspect(dem)
plot(
    dem, text_values = TRUE, breaks = "equal",
    col = hcl.colors(11, "Spectral"), main = "input (elevation)"
)
plot(
    dem_aspect, text_values = TRUE, breaks = "equal",
    col = hcl.colors(11, "Spectral"), main = "output (aspect)"
)

# Larger example
data(carmel)
carmel_aspect = aspect(carmel)
plot(
    carmel, breaks = "equal",
    col = hcl.colors(11, "Spectral"), main = "input (elevation)"
)
plot(
    carmel_aspect, breaks = "equal",
    col = hcl.colors(11, "Spectral"), main = "output (aspect)"
)
```
**carmel**  
*Digital Elevation Model of Mount Carmel*

**Description**

A stars object representing a Digital Elevation Model (DEM) Digital Elevation Model of Mount Carmel, at 90m resolution

**Usage**

```r
carmel
```

**Format**

A stars object with 1 attribute:

- **elevation** Elevation above sea level, in meters

**Examples**

```r
plot(carmel, breaks = "equal", col = terrain.colors(11))
```

---

**CI**  
*Calculate the Convergence Index (CI) from a slope raster*

**Description**

Calculates the Convergence Index (CI) given a topographic slope raster. Input and output are rasters of class stars, single-band (i.e., only "x" and "y" dimensions), with one attribute.

**Usage**

```r
CI(x, k, na.rm = FALSE, na_flag = -9999)
```

**Arguments**

- **x**  
  A raster (class stars) with two dimensions: x and y, i.e., a single-band raster, representing aspect in decimal degrees clockwise from north, possibly including -1 to specify flat terrain, such as returned by function `aspect`.

- **k**  
  Neighborhood size around focal cell. Must be an odd number. For example, k=3 implies a 3*3 neighborhood.

- **na.rm**  
  Should NA values be ignored when calculating CI? Default is FALSE, i.e., when at least one aspect value in the neighborhood is NA the CI is also set to NA.

- **na_flag**  
  Value used to mark NA values in C code. This should be set to a value which is guaranteed to be absent from the input raster x (default is -9999).
Value

A `stars` raster with CI values.

Note

The raster is "padded" with \((k-1)/2\) more rows and columns of NA values on all sides, so that the neighborhood of the outermost rows and columns is still a complete neighborhood. Those rows and columns are removed from the final result before returning it. Aspect values of \(-1\), specifying flat terrain, are assigned with a CI value of 0 regardless of their neighboring values.

References

The Convergence Index algorithm is described in:


Examples

```r
# Small example
data(dem)
dem_asp = aspect(dem)
dem_ci = CI(dem_asp, k = 3)
r = c(dem, round(dem_ci, 1), along = 3)
r = st_set_dimensions(r, 3, values = c("input (aspect)", "output (CI, k=3)"))
plot(r, text_values = TRUE, breaks = "equal", col = terrain.colors(10), mfrow = c(1, 2))

# Larger example
data(golan)
golan_asp = aspect(golan)
golan_ci = CI(golan_asp, k = 25)
plot(golan_asp, breaks = "equal", col = hcl.colors(11, "Spectral"), main = "input (aspect)"
plot(golan_ci, breaks = "equal", col = hcl.colors(11, "Spectral"), main = "output (CI, k=25)"
```

---

**dem**

Small Digital Elevation Model

Description

A `stars` object representing a small 13*11 Digital Elevation Model (DEM), at 90m resolution

Usage

dem
detrend

Format

A stars object with 1 attribute:

**elevation**  Elevation above sea level, in meters

Examples

plot(dem, text_values = TRUE, breaks = "equal", col = terrain.colors(11))

detrend  *Detrend a Digital Elevation Model*

Description

Detrends a Digital Elevation Model (DEM) raster, by subtracting a trend surface. The trend is computed using `mgcv::gam` or `mgcv::bam` (when `parallel>1`) with formula \( z \sim s(x, y) \).

Usage

detrend(x, parallel = 1)

Arguments

- **x**  A two-dimensional stars object representing the DEM
- **parallel**  Number of parallel processes. With `parallel=1` uses ordinary, non-parallel processing.

Value

A two-dimensional stars object, with two attributes:

- **resid** - the detrended result, i.e., "residual"
- **trend** - the estimated "trend" which was subtracted from the actual elevation to obtain resid

Examples

# Small example
data(dem)
dem1 = detrend(dem)
dem1 = st_redimension(dem1)
dem1 = st_set_dimensions(dem1, 3, values = c("resid", "trend"))
plot(round(dem1), text_values = TRUE, col = terrain.colors(11))

# Larger example 1
data(carmel)
carmel1 = detrend(carmel, parallel = 2)
carmel1 = st_redimension(carmel1)
carmel1 = st_set_dimensions(carmel1, 3, values = c("resid", "trend"))
dist_to_nearest

plot(carmel1, col = terrain.colors(11))

# Larger example 2
data(golan)
golan1 = detrend(golan, parallel = 2)
golan1 = st_redimension(golan1)
golan1 = st_set_dimensions(golan1, 3, values = c("resid", "trend"))
plot(golan1, col = terrain.colors(11))

---

## dist_to_nearest

### Calculate raster of distances to nearest feature

#### Description

Given a `stars` raster and an `sf` vector layer, returns a new raster with the distances of each cell centroid to the nearest feature in the vector layer.

#### Usage

```r
dist_to_nearest(x, v, progress = TRUE)
```

#### Arguments

- `x`: A `stars` layer, used as a "grid" for distance calculations
- `v`: An `sf`, `sfc` or `sfg` object
- `progress`: Display progress bar? The default is `TRUE`

#### Value

A `stars` raster with distances to nearest feature

#### Examples

```r
# Sample 'sf' layer
x = st_point(c(0,0))
y = st_point(c(1,1))
x = st_sfc(x, y)
x = st_sf(x)
x = st_buffer(x, 0.5)

# Make grid
r = make_grid(x, res = 0.1, buffer = 0.5)
d = dist_to_nearest(r, x, progress = FALSE)

# Plot
plot(d, breaks = "equal", axes = TRUE, reset = FALSE)
plot(st_geometry(x), add = TRUE, pch = 4, cex = 3)
```
extract2  

Extract raster values by lines or polygons

Description

Extract raster values by lines or polygons, summarizing for each feature using a function specified by the user. This function is aimed to reproduce (some of) the functionality of raster::extract.

Usage

extract2(x, v, fun, progress = TRUE, ...)

Arguments

- **x**: A `stars` object
- **v**: An `sf` layer that determines values to extract
- **fun**: A function to summarize cell values per feature/band
- **progress**: Display progress bar? The default is `TRUE`
- **...**: Further arguments passed to `fun`

Value

A vector (single-band raster) or matrix (multi-band raster) with the extracted and summarized values

Examples

```r
# Polygons
pol = st_bbox(landsat)
pol = st_as_sfc(pol)
set.seed(1)
pol = st_sample(pol, 5)
pol = st_buffer(pol, 100)
pol = c(pol, pol)

# Plot
plot(landsat[,,,1,drop=TRUE], reset = FALSE)
plot(pol, add = TRUE)

# Single-band raster
aggregate(landsat[,,,1,drop=TRUE], pol, mean, na.rm = TRUE)[[1]]  # Duplicated areas get 'NA'
extract2(landsat[,,,1,drop=TRUE], pol, mean, na.rm = TRUE, progress = FALSE)

# Multi-band example
extract2(landsat, pol, mean, na.rm = TRUE, progress = FALSE)

# Lines
```
lines = st_cast(pol, "LINESTRING")

# Single-band raster
extract2(landsat[, , 1, drop = TRUE], lines, mean, na.rm = TRUE, progress = FALSE)

# Multi-band example
extract2(landsat, lines, mean, na.rm = TRUE, progress = FALSE)

---

**flowlength**  
*Calculate flow length*

**Description**

Calculates flow length for each pixel in a Digital Elevation Model (DEM) raster. Inputs and output are rasters of class `stars`, single-band (i.e., only "x" and "y" dimensions), with one attribute.

**Usage**

`flowlength(elev, veg, progress = TRUE)`

**Arguments**

- `elev`: A numeric `stars` raster representing a Digital Elevation Model (DEM).
- `veg`: A matching logical `stars` raster representing vegetation presence. `TRUE` values represent vegetated cells where flow is absorbed (i.e. sinks), `FALSE` values represent cells where flow is unobstructed.
- `progress`: Display progress bar? The default is `TRUE`.

**Value**

A numeric `stars` raster where each cell value is flow length, in resolution units.

**References**

The algorithm is described in:


**Examples**

# Example from Fig. 2 in Mayor et al. 2008

```r
elev = rbind(
  c(8, 8, 8, 8, 9, 8, 9),
  c(7, 7, 7, 7, 9, 7, 7),
  c(6, 6, 6, 6, 5, 7),
```
c(4, 5, 5, 3, 5, 4, 7),
c(4, 5, 4, 5, 4, 6, 5),
c(3, 3, 3, 2, 3, 3),
c(2, 2, 2, 3, 4, 1, 3)
)
veg = rbind(
c(TRUE, TRUE, TRUE, TRUE, FALSE, FALSE, TRUE),
c(TRUE, TRUE, TRUE, TRUE, TRUE, FALSE, TRUE),
c(FALSE, FALSE, FALSE, FALSE, FALSE, FALSE, FALSE),
c(FALSE, TRUE, FALSE, FALSE, FALSE, FALSE, TRUE),
c(TRUE, TRUE, FALSE, FALSE, FALSE, FALSE, FALSE),
c(TRUE, TRUE, TRUE, FALSE, FALSE, FALSE, FALSE),
c(FALSE, TRUE, TRUE, FALSE, FALSE, TRUE, TRUE)
)
elev = matrix_to_stars(elev)
veg = matrix_to_stars(veg)

# Calculate flow length
fl = flowlength(elev, veg, progress = FALSE)

# Plot
plot(
  round(elev, 1), text_values = TRUE, breaks = "equal",
  col = terrain.colors(6), main = "input (elevation)"
)
plot(
  veg*1, text_values = TRUE, breaks = "equal",
  col = rev(terrain.colors(2)), main = "input (vegetation)"
)
plot(
  round(fl, 1), text_values = TRUE, breaks = "equal",
  col = terrain.colors(6), main = "output (flowlength)"
)

# Larger example
data(carmel)
elev = carmel
elev[is.na(elev)] = 0
veg = elev > 100
fl = flowlength(elev, veg, progress = FALSE)
plot(fl, breaks = "equal", col = hcl.colors(11), main = "flowlength (m)")

---

**focal2**

*Apply a focal filter on a raster*

**Description**

Applies a focal filter with weighted neighborhood $w$ on a raster. The weights ($w$) can be added to, subtracted from, multiplied by or divided with the raster values (as specified with `weight_fun`).
The focal cell is then taken as the mean, sum, minimum or maximum of the weighted values (as specified with `fun`). Input and output are rasters of class `stars`, single-band (i.e., only “x” and “y” dimensions), with one attribute.

Usage

```r
focal2(
  x,
  w,
  fun = "mean",
  weight_fun = "*",
  na.rm = FALSE,
  mask = FALSE,
  na_flag = -9999
)
```

Arguments

- **x**: A raster (class `stars`) with one attribute and two dimensions: x and y, i.e., a single-band raster.
- **w**: Weights matrix defining the neighborhood size around the focal cell, as well as the weights. For example, `matrix(1,3,3)` implies a neighborhood of size 3*3 with equal weights of 1 for all cells. The matrix must be square, i.e., with an odd number of rows and columns.
- **fun**: A function to aggregate the resulting values for each neighborhood. Possible values are: "mean", "sum", "min", "max", and "mode". The default is "mean", i.e., the resulting values per neighborhood are averaged before being assigned to the new focal cell value.
- **weight_fun**: An operator which is applied on each pair of values comprising the cell value and the respective weight value, as in `raster_value-weight`. Possible values are: "+", "-", "*", "/". The default is "*", i.e., each cell value is multiplied by the respective weight.
- **na.rm**: Should NA values in the neighborhood be removed from the calculation? Default is FALSE.
- **mask**: If TRUE, pixels with NA in the input are set to NA in the output as well, i.e., the output is “masked” using the input (default is FALSE).
- **na_flag**: Value used to mark NA values in C code. This should be set to a value which is guaranteed to be absent from the input raster x (default is -9999).

Value

The filtered `stars` raster.

Note

The raster is "padded" with `(nrow(w)-1)/2` more rows and columns of NA values on all sides, so that the neighborhood of the outermost rows and columns is still a complete neighborhood. Those rows and columns are removed from the final result before returning it. This means, for instance, that the outermost rows and columns in the result will be NA when using `na.rm=FALSE`. 
focal2r

Apply a focal filter on a raster (R)

Description
Applies a focal filter with neighborhood size \( k \times k \) on a raster (class stars), using R code. This function is relatively slow, provided here mainly for testing purposes or for custom using functions which are not provided by focal2.

Usage
focal2r(x, w, fun, mask = FALSE, ...)

Arguments

x
A raster (class stars) with two dimensions: \( x \) and \( y \), i.e., a single-band raster

w
Weights matrix defining the neighborhood size around the focal cell, as well as the weights. For example, matrix(1, 3, 3) implies a neighborhood of size 3\( \times 3 \) with equal weights of 1 for all cells. Focal cell values are multiplied by the matrix values before being passed to function fun. The matrix must be square, i.e., with an odd number of rows and columns.

fun
A function to be applied on each neighborhood, after it has been multiplied by the matrix. The function needs to accept a vector (of length equal to length(w) and return a vector of length 1

References
The function interface was inspired by function raster::focal. The C code for this function is a modified and expanded version of the C function named applyKernel included with R package spatialfil.

Examples

# Small example
data(dem)
dem_mean3 = focal2(dem, matrix(1, 3, 3), "mean"
\( r = c(dem, round(dem\_mean3, 1), along = 3)\)
\( r = st\_set\_dimensions(r, 3, values = c(\"input\", \"output (mean, k=3)\")\)
plot(r, text_values = TRUE, breaks = "equal", col = terrain.colors(11))

# Larger example
data(carmel)
carmel_mean15 = focal2(carmel, matrix(1, 15, 15), "mean"
\( r = c(carmel, carmel\_mean15, along = 3)\)
\( r = st\_set\_dimensions(r, 3, values = c(\"input\", \"output (mean, k=15)\")\)
plot(r, breaks = "equal", col = terrain.colors(11))
You can run the following code examples in R to understand the functionality:

```r
# Small example
data(dem)
dem1 = focal2r(dem, matrix(1,3,3), mean, na.rm = TRUE)
dem2 = focal2r(dem, matrix(1,3,3), min, na.rm = TRUE)
dem3 = focal2r(dem, matrix(1,3,3), max, na.rm = TRUE)
r = c(dem, round(dem1, 1), dem2, dem3, along = 3)
r = st_set_dimensions(r, 3, values = c("input", "mean", "min", "max"))
plot(r, text_values = TRUE, breaks = "equal", col = terrain.colors(10))

# Larger example
data(carmel)
carmel1 = focal2r(carmel, matrix(1,3,3), mean, na.rm = TRUE, mask = TRUE)
carmel2 = focal2r(carmel, matrix(1,9,9), mean, na.rm = TRUE, mask = TRUE)
carmel3 = focal2r(carmel, matrix(1,15,15), mean, na.rm = TRUE, mask = TRUE)
r = c(carmel, carmel1, carmel2, carmel3, along = 3)
r = st_set_dimensions(r, 3, values = c("input", "k=3", "k=9", "k=15"))
plot(r, breaks = "equal", col = terrain.colors(100))
```
Value

An sf layer with the footprints (i.e., bounding box polygons) of the rasters

Examples

```r
# Create sample files
file1 = tempfile(fileext = ".tif")
file2 = tempfile(fileext = ".tif")
file3 = tempfile(fileext = ".tif")
r1 = landsat[,1:100, 1:100,]
r2 = landsat[,101:200, 101:200,]
r3 = landsat[,21:40, 51:120,]
write_stars(r1, file1)
write_stars(r2, file2)
write_stars(r3, file3)

# Calculate footprints
files = c(file1, file2, file3)
pol = footprints(files)
pol

# Plot
plot(pol)
```

---

golan  

*Digital Elevation Model of Golan Heights*

Description

A stars object representing a Digital Elevation Model (DEM) Digital Elevation Model of part of the Golan Heights and Lake Kinneret, at 90m resolution

Usage

`golan`

Format

A stars object with 1 attribute:

- **elevation**  Elevation above sea level, in meters

Examples

```r
plot(golan, breaks = "equal", col = terrain.colors(11))
```
**Description**

A `stars` object representing an RGB image of part of Mount Carmel, at 30m resolution. The data source is Landsat-8 Surface Reflectance product.

**Usage**

landsat

**Format**

A `stars` object with 1 attribute:

- `refl` Reflectance, numeric value between 0 and 1

**Examples**

```r
plot(landsat, breaks = "equal")
```

---

**layer_to_matrix**

*Get stars layer values as matrix*

**Description**

Extracts the values of a single layer in a `stars` object to a matrix.

**Usage**

`layer_to_matrix(x, check = TRUE)`

**Arguments**

- `x` A `stars` raster with one attribute and two dimensions, `x` and `y`, i.e., a single-band raster.
- `check` Whether to check (and fix if necessary) that input has one attribute, one layer, and `x-y` as dimensions 1-2 (default is `TRUE`).

**Value**

A matrix with the layer values, having the same orientation as the raster (i.e., rows represent the `y`-axis and columns represent the `x`-axis).
Examples

data(dem)
m = layer_to_matrix(dem)
m

layer_to_vector  Get stars layer values as vector

Description

Extracts the values of a single layer in a stars object to a vector. Cell values are ordered from top-left corner to the right.

Usage

layer_to_vector(x, check = TRUE)

Arguments

x A raster (class stars) with two dimensions: x and y, i.e., a single-band raster.
check Whether to check (and fix if necessary) that input has one attribute, one layer and x-y as dimensions 1-2 (default is TRUE).

Value

A vector with cell values, ordered by rows, starting from the top left corner (north-west) and to the right.

Examples

data(dem)
v = layer_to_vector(dem)
v
**Description**

Create 'stars' raster grid from bounding box of 'sf' vector layer, possibly buffered, with specified resolution.

**Usage**

```r
make_grid(x, res, buffer = 0)
```

**Arguments**

- `x`: An `sf`, `sfc` or `sfg` object
- `res`: Required grid resolution, in CRS units of `x`
- `buffer`: Buffer size around `x` (default is 0, i.e., no buffer)

**Value**

A `stars` raster with the grid, with all cell values equal to 1

**Examples**

```r
# Sample 'sf' layer
x = st_point(c(0,0))
y = st_point(c(1,1))
x = st_sfc(x, y)
x = st_sf(x)

# Make grid
r = make_grid(x, res = 0.1, buffer = 0.5)
r[[1]][] = rep(1:3, length.out = length(r[[1]]))

# Plot
plot(r, axes = TRUE, reset = FALSE)
plot(st_geometry(x), add = TRUE, pch = 4, cex = 3, col = "red")
```

---

**matrix_extend**

**Extend matrix**

**Description**

Adds `n` rows and columns with NA values on all sides of a matrix.
Usage

matrix_extend(m, n = 1, fill = NA)

Arguments

m  A matrix
n  By how many rows/columns to extend the matrix on each side?
fill  Fill value (default is NA)

Value

An extended matrix

Examples

m = matrix(1:6, nrow = 2, ncol = 3)
m
matrix_extend(m, 1)
matrix_extend(m, 2)
matrix_extend(m, 3)

matrix_get_neighbors

Get neighboring cell values for given matrix cell

Description

Get the values of a k*k neighborhood, as vector and by row, given a matrix, k, and focal cell position (row and column).

Usage

matrix_get_neighbors(m, pos, k = 3)

Arguments

m  A matrix.
pos  The focal cell position, a numeric vector of length two of the form c(row, column).
k  Neighborhood size around the focal cell. For example, k=3 implies a neighborhood of size 3*3. Must be an odd positive integer.

Value

A vector with cell values, ordered by rows, starting from the top left corner of the neighborhood and to the right. When neighborhood extends beyond matrix bounds, only the "existing" values are returned.
matrix_to_stars

Examples

m = matrix(1:12, nrow = 3, ncol = 4)
m
matrix_get_neighbors(m, pos = c(2, 2), k = 3)
matrix_get_neighbors(m, pos = c(2, 2), k = 5)
matrix_get_neighbors(m, pos = c(2, 2), k = 7) # Same result

matrix_to_stars Convert matrix to stars

Description

Converts matrix to a single-band stars raster, conserving the matrix orientation where rows become the y-axis and columns become the y-axis. The bottom-left corner of the axis is set to (0,0) coordinate, so that x and y coordinates are positive across the raster extent.

Usage

matrix_to_stars(m, res = 1)

Arguments

m A matrix
res The cell size, default is 1

Value

A stars raster

Examples

data(volcano)
r = matrix_to_stars(volcano, res = 10)
plot(r)
matrix_trim  Trim matrix

Description
Removes n rows and columns with NA values on all sides of a matrix.

Usage
matrix_trim(m, n = 1)

Arguments
m  A matrix
n  By how many rows/columns to trim the matrix on each side?

Value
A trimmed matrix, or NULL if trimming results in an "empty" matrix.

Examples
m = matrix(1:80, nrow = 8, ncol = 10)
m
matrix_trim(m, 1)
matrix_trim(m, 2)
matrix_trim(m, 3)
matrix_trim(m, 4)

mode_value  Mode

Description
Find the mode (i.e., most common value) in a numeric vector. In case of ties, the first encountered value is returned.

Usage
mode_value(x, na_flag = -9999)

Arguments
x  A numeric or logical vector
na_flag  Value used to mark NA values in C code. This should be set to a value which is guaranteed to be absent from the input vector x (default is -9999).
normalize_2d

Value

The mode, numeric vector of length 1

Examples

```r
x = c(3, 2, 5, 5, 3, 10, 2, 5)
mode_value(x)
```

---

**normalize_2d**

Normalize a 2D 'stars' object

Description

Check, and possibly correct, that the input stars object:

- Has exactly one attribute.
- Has exactly two dimensions.
- The dimensions are spatial, named x and y (in that order).

Usage

```r
normalize_2d(x)
```

Arguments

- **x** A stars object

Value

A new stars object

Examples

```r
# Small example
data(dem)
normalize_2d(dem)
```
normalize_3d  Normalize a 3D 'stars' object

Description
Check, and possibly correct, that the input stars object:

- Has exactly one attribute.
- Has exactly three dimensions.
- The first two dimensions are spatial, named x and y (in that order).

Usage
normalize_3d(x)

Arguments
x  A stars object

Value
A new stars object

Examples
# Small example
data(landsat)
normalize_3d(landsat)

rgb_to_greyscale  Convert RGB to greyscale

Description
Convert a 3-band RGB raster to 1-band greyscale raster. Based on wvtool::rgb2gray.

Usage
rgb_to_greyscale(x, rgb = 1:3, coefs = c(0.3, 0.59, 0.11))

Arguments
x  A three-dimensional stars object with RGB values
rgb  Indices of RGB bands, default is c(1,2,3)
coefs  RGB weights, default is c(0.3,0.59,0.11)
**Value**

A two-dimensional stars object greyscale values

**Examples**

data(landsat)
plot(landsat, rgb = 1:3)
landsat_grey = rgb_to_greyscale(landsat)
plot(landsat_grey, breaks = "equal")

---

**Description**

Calculates topographic slope given a Digital Elevation Model (DEM) raster. Input and output are rasters of class stars, single-band (i.e., only “x” and “y” dimensions), with one attribute.

**Usage**

`slope(x, na_flag = -9999)`

**Arguments**

- `x` A raster (class stars) with two dimensions: x and y, i.e., a single-band raster, representing a DEM.
- `na_flag` Value used to mark NA values in C code. This should be set to a value which is guaranteed to be absent from the input raster x (default is -9999).

**Value**

A stars raster with topographic slope, i.e., the azimuth where the terrain is tilted towards, in decimal degrees (0-360) clockwise from north.

**Note**

Slope calculation results in NA when at least one of the cell neighbors is NA, including the outermost rows and columns. Given that the focal window size in slope calculation is 3*3, this means that the outermost one row and one column are given an slope value of NA.

**References**

The topographic slope algorithm is based on the *How slope works* article in the ArcGIS documentation:

Examples

# Small example
data(dem)
dem_slope = slope(dem)
plot(
    dem, text_values = TRUE, breaks = "equal",
    col = hcl.colors(11, "Spectral"), main = "input (elevation)"
)

plot(
    dem_slope, text_values = TRUE, breaks = "equal",
    col = hcl.colors(11, "Spectral"), main = "output (slope)"
)

# Larger example
data(carmel)
carmel_slope = slope(carmel)
plot(
    carmel, breaks = "equal",
    col = hcl.colors(11, "Spectral"), main = "input (elevation)"
)
plot(
    carmel_slope, breaks = "equal",
    col = hcl.colors(11, "Spectral"), main = "output (slope)"
)

trim2

Remove empty outer rows and columns

Description

Removes complete outer rows and columns which have NA values.

Usage

trim2(x)

Arguments

x A two-dimensional stars object

Value

A new stars object with empty outer rows and columns removed
Examples

```r
# Single-band example
data(dem)
dem[[1]][1,] = NA
dem1 = trim2(dem)

# Multi-band example
data(landsat)
landsat[[1]][1:100,,] = NA
landsat1 = trim2(landsat)
```

**Description**

Creates a matrix with directions (i.e., azimuth) to central cell, of specified size \( k \). The matrix can be used as weight matrix when calculating the convergence index (see Examples).

**Usage**

```r
w_azimuth(k)
```

**Arguments**

- **k**: Neighborhood size around focal cell. Must be an odd number. For example, \( k=3 \) implies a 3x3 neighborhood.

**Value**

A matrix where each cell value is the azimuth from that cell towards the matrix center.

**Examples**

```r
m = w_azimuth(3)
m
m = w_azimuth(5)
m
```
w_circle

Create matrix with circular weight pattern

Description

Creates a matrix with where a circular pattern is filled with values of 1 and the remaining cells are filled with values of 0 (see Examples).

Usage

w_circle(k)

Arguments

k

Neighborhood size around focal cell. Must be an odd number. For example, k=3 implies a 3*3 neighborhood.

Value

A matrix with a circular pattern.

Examples

```r
m = w_circle(3)
image(m, asp = 1, axes = FALSE)
m = w_circle(5)
image(m, asp = 1, axes = FALSE)
m = w_circle(15)
image(m, asp = 1, axes = FALSE)
m = w_circle(35)
image(m, asp = 1, axes = FALSE)
m = w_circle(91)
image(m, asp = 1, axes = FALSE)
m = w_circle(151)
image(m, asp = 1, axes = FALSE)
```
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