Package 'StrucDiv'

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Type Package

Title Spatial Structural Diversity Quantification in Raster Data

Version 0.1.1

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Description Spatial structural diversity refers to the spatial arrangement of landscape elements and can reveal itself as landscape features, such as patches and line features. The 'R' package 'StrucDiv' provides methods to quantify spatial structural diversity in continuous remote sensing data, or in other data in gridded field format. The methods are based on second-order texture metrics, considering the spatial arrangement of pixel pairs.

Depends R (>= 3.5.0)

License GPL (>= 3)

Imports Rcpp (>= 1.0.4), raster (>= 3.1.5)

Suggests testthat, knitr, rmarkdown

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R topics documented:

`metric` *Spatial structural diversity metrics*

Description

The functions `entropy` , `entropyNorm`, `contrast`, `dissimilarity` and `homogeneity` are the spatial structural diversity metrics used in the default configuration of `StrucDiv`. Structural diversity entropy is entropy with different `delta` parameters. Shannon entropy is employed, when `delta` = "0". Shannon entropy has a window-dependent maximum. Additionally, the value gradient is considered when `delta` = "1" or `delta` = "2". The values of structural diversity entropy with `delta` = "1" or `delta` = "2" are not restricted and depend on the values of the input raster. The metric `entropyNorm` is Shannon entropy normalized over maximum entropy, which depends on the size of the moving window. The metric `entropyNorm` ranges between 0 and 1. The metrics `contrast`, `dissimilarity` consider the value gradient, their values are not restricted and depend on the values of the input raster. The metric `homogeneity` quantifies the closeness of empirical probabilities to the diagonal and ranges between 0 and 1. the metric `homogeneity` is 1 when all pixel pairs are the same and approaches 0 as differences increase.

Usage

```
entropy(rank, delta, Hetx, SpatMat, nrp, narm, display_progress, ...)

entropyNorm(rank, delta, Hetx, SpatMat, nrp, narm, display_progress, ...)

contrast(rank, delta, Hetx, SpatMat, nrp, narm, display_progress, ...)

dissimilarity(rank, delta, Hetx, SpatMat, nrp, narm, display_progress, ...)

homogeneity(rank, delta, Hetx, SpatMat, nrp, narm, display_progress, ...)
```

Arguments

`rank`	logical. Should values be replaced with ranks in each gray level co-occurrence matrix (GLCM)? Defaults to `FALSE`.
`delta`	character, takes 3 options: `"0"`, `"1"`, or `"2"`. The parameter `delta` is the difference weight parameter, it defines how the differences between pixel values within a pixel pair should be weighted. If `rank` = `TRUE`, delta defines how the differences between ranks should be weighted. The default value is `"0"` (no weight). Set `delta` = `"1"` for absolute difference weight, or `delta` = `"2"` for

squared difference weight. The `delta` parameter can only be set when the metric `entropy` is used. The metric `dissimilarity` automatically employs `delta = "1"`, and `contrast` employs `delta = "2"`.

`Hetx` the spatial structural diversity matrix that is returned by an internal function to the `StrucDiv` function. the spatial structural diversity metric is calculated on every element of the GLCM, which generates the spatial structural diversity matrix `Hetx`. The sum of this matrix represents the spatial structural diversity estimate of the moving window, the size of which is defined by `wsl` in the `StrucDiv` function.

`SpatMat` the GLCM that is returned by an internal function to the `StrucDiv` function.

`nrp` integer. The total number of pixel pairs, which is calculated internally and passed to the spatial structural diversity metric functions. The total number of pixel pairs is defined by the size of the moving window (`wsl x wsl`), and by the angle.

`narm` logical. Defines how missing values are treated, and is automatically set to 0 if na.handling = na.pass, and to 1 if na.handling = na.omit.

`display_progress` logical. If TRUE the progress bar is displayed.

`...` possible further arguments.

Details

This function is used internally and is called as an argument to `StrucDiv`.

Value

The output is a raster layer with the same dimensions as the input raster and is called a (spatial) structural diversity map. It represents spatial structural diversity quantified on the spatial scale that is defined by the size of the moving window. When `na.handling = na.pass`, then the output map will have an NA-edge of 0.5*(`wsl`-1), and it will contain more missing values than the input raster.

`ndvi` *NDVI*

Description

NDVI

Usage

```
ndvi
```

Format

A matrix with 221 rows and 1092 columns. Mean Normalized Difference Vegetation Index (NDVI).

`Modified remote sensing product` MOD13A1v006

`Device` MODIS sensor

`Year` 2018

`Aggregation` Mean aggregation over the growing season 2018

`Location` Study region in North East Eurasia

`Data quality` Only pixels with sufficient quality flags were used.

`NA handling` NA gaps were filled with a local neighborhood average.

`Value range` NDVI values below zero were excluded. NDVI values range between 0 and 1.

`Data retrieval` Data was pre-processed and downloaded from Google Earth Engine.

For further details, see https://lpdaac.usgs.gov/products/mod13q1v006/ and https://earthengine.google.com/

`ndvi.15gl` *NDVI, 15 gray levels*

Description

NDVI, 15 gray levels

Usage

```
ndvi.15gl
```

Format

A matrix with 221 rows and 1092 columns. Mean Normalized Difference Vegetation Index (NDVI), with reduced number of gray levels (15).

`Modified remote sensing product` MOD13A2v006

`Device` MODIS sensor

`Year` 2018

`Aggregation` Mean aggregation over the growing season 2018

`Gray level reduction` Data was binned into 15 bins of equal size.

`Location` Study region in North East Eurasia

`Data quality` Only pixels with sufficient quality flags were used.

`NA handling` NA gaps were filled with a local neighborhood average.

`Value range` NDVI values below zero were excluded. NDVI values range between 0 and 1.

`Data retrieval` Data was pre-processed and downloaded from Google Earth Engine.

For further details, see https://lpdaac.usgs.gov/products/mod13q1v006/ and https://earthengine.google.com/

`StrucDiv` *Calculate spatial structural diversity for an arbitrary raster layer.*

Description

This is a wrapper function that returns a spatial structural diversity map as a raster layer. Pixels are considered as pairs in user-specified distances and angles. Angles include horizontal and vertical direction, and the diagonals at 45° and 135°. The direction-invariant version considers all angles. The frequencies of pixel pairs are normalized by the total number of pixel pairs, which returns the gray level co-occurrence matrix (GLCM). The total number of pixel pairs depends on the extent of the area within which pixel pairs are counted, i.e. on the spatial scale. The spatial scale is defined by the window side length (`wsl`) of a moving window. The values in a GLCM are the same values that occur in the area within which pixel pairs were counted, therefore they can differ between GLCMs. In each GLCM, pixel values can be replaced with ranks. Diversity metrics are calculated on every element of the GLCM, their sum is assigned to the center pixel of the moving window and represents spatial structural diversity of the area captured by the moving window. The final map is called a '(spatial) structural diversity map' and is returned as a raster layer with the same dimensions as the input raster.

Usage

```
StrucDiv(
  x,
  wsl,
  dist = 1,
  angle = c("all", "horizontal", "vertical", "diagonal45", "diagonal135"),
  rank = FALSE,
  fun,
  delta = c("0", "1", "2"),
  na.handling = na.pass,
  padValue = NA,
  aroundTheGlobe = FALSE,
  filename = "",
  verbose = TRUE,
  ...
)
```

Arguments

`x`	raster layer. Input raster layer for which spatial structural diversity should be calculated.
`wsl`	uneven integer. The window side length, `wsl` x `wsl` defines the size of the moving window. The window must be smaller than the dimensions of the input raster. The moving window defines the spatial scale on which spatial structural diversity is quantified.
`dist`	integer. The distance between two pixels that should be considered as a pair, defaults to dist = 1 (direct neighbors).

angle	string. The angle on which pixels should be considered as pairs. Takes 5 options: "horizontal", "vertical", "diagonal45", "diagonal135", "all". "all" is the direction-invariant version that considers all 4 angles. Defaults to "all".
rank	logical. Should pixel values be replaced with ranks in each GLCM? Defaults to FALSE.
fun	function, the diversity metric. Takes one of the following: entropy, entropyNorm, contrast, dissimilarity, or homogeneity. Structural diversity entropy is entropy with different delta parameters. Shannon entropy is employed, when delta = "0". Shannon entropy has a scale-dependent maximum. Additionally, the value gradient is considered when delta = "1" or delta = "2". The values of structural diversity entropy with delta = "1" or delta = "2" are not restricted and depend on the values of the input raster. entropyNorm is Shannon entropy normalized over maximum entropy, which depends on the size of the moving window. The metric entropyNorm ranges between 0 and 1. Contrast, dissimilarity and homogeneity are established second-order texture metrics. Contrast and dissimilarity consider the value gradient, their values are not restricted and depend on the values of the input raster. Homogeneity quantifies the closeness of empirical probabilities to the diagonal and ranges between 0 and 1. Homogeneity is 1 when all pixel pairs are the same and approaches 0 as differences increase.
delta	character, takes three options: "0", "1", or "2". Delta is the difference weight, it defines how the differences between pixel values within a pixel pair should be weighted. If rank = TRUE, delta defines how the differences between ranks should be weighted. The default value is "0" (no weight). Set delta = "1" for absolute difference weight, or delta = "2" for squared difference weight. The delta parameter can only be set when the metric entropy is used. Dissimilarity automatically employs delta = "1", and contrast employs delta = "2".
na.handling	na.omit or na.pass. If na.handling = na.omit, NAs are ignored, diversity metrics are calculated with less values. In this case the GLCM does not sum to 1. If na.handling = na.pass and if there is at least one missing value inside the moving window, an NA is assigned to the center pixel. Therefore, the diversity map will contain more NAs than the input raster layer. Defaults to na.pass.
padValue	numeric. The value of the padded cells at the edges of the input raster. Defaults to NA.
aroundTheGlobe	logical. If the input raster goes around the whole globe, set aroundTheGlobe = TRUE, and the input raster will be "glued together" from both sides to calculate spatial structural diversity without edge effects on the sides. Defaults to FALSE.
filename	character. If the output raster should be written to a file, define file name (optional).
verbose	logical. If TRUE a progress bar is printed
...	possible further arguments.

Details

The memory requirement of the function is determined by `raster::canProcessInMemory()`. If the raster file cannot be processed in memory, its size needs to be reduced before `StrucDiv` can be used.

Value

The output is a (spatial) structural diversity map, returned as a raster layer with the same dimensions as the input raster. When `na.handling = na.pass`, then the output map will have an NA-edge of 0.5*(`wsl`-1), and it will contain more missing values than the input raster. The output represents spatial structural diversity quantified on a spatial scale defined by the size of the moving window.

Examples

```
# Calculate contrast on a small raster file with random normal distribution
a <- raster::raster(matrix(rnorm(648), 18, 36))
raster::plot(a)
contrast_a <- StrucDiv(a, 3, fun = contrast, na.handling = na.omit, rank = FALSE)
raster::plot(contrast_a)

# Calculate dissimilarity on a small raster file with random normal distribution
b <- raster::raster(matrix(rnorm(100), 10, 10))
raster::plot(b)
dissim_b <- StrucDiv(b, 5, fun = dissimilarity, na.handling = na.pass, rank = FALSE)
raster::plot(dissim_b)
```

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