

# Package ‘SpatialPack’

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**Title** Tools for Assessment the Association Between Two Spatial Processes

**Description** Tools to assess the association between two spatial processes. Currently, several methodologies are implemented: A modified t-test to perform hypothesis testing about the independence between the processes, a suitable nonparametric correlation coefficient, the codispersion coefficient, and an F test for assessing the multiple correlation between one spatial process and several others. Functions for image processing and computing the spatial association between images are also provided. SpatialPack gives methods to complement methodologies that are available in geoR for one spatial process.

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clipping	<i>Clipping image</i>
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### Description

This function returns the image which restricts pixel value from the specified range.

### Usage

```
clipping(img, low = 0, high = 1)
```

### Arguments

img	input grayscale image matrix.
low	lowest value.
high	highest value.

### Value

grayscale image matrix with the same size as 'img'.

### Examples

```
data(texmos2)
plot(as.raster(texmos2))

# the appearance of next one doesn't change because of normalization
x <- normalize(2 * texmos2)
plot(as.raster(x))
title(main = "Doubled pixel value with normalization", font.main = 1)

# the next one is saturated as expected
x <- clipping(2 * texmos2)
plot(as.raster(x))
title(main = "Doubled pixel value with clipping", font.main = 1)
```

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codisp	<i>Codispersion Coefficient</i>
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### Description

Computes the codispersion coefficient between two spatial variables for a given number of classes for the lag distance.

### Usage

```
codisp(x, y, coords, nclass = 13)
```

### Arguments

x	an n-dimensional vector of data values.
y	an n-dimensional vector of data values.
coords	an n-by-2 matrix containing coordinates of the n data locations in each row.
nclass	a single number giving the number of cells for the codispersion coefficient. The default is 13. If this argument is NULL Sturges' formula is used.

### Details

The procedure computes the codispersion coefficient for two spatial sequences defined on general (non-rectangular) grids. First, a given number of bins are constructed for the lag distance. Then the codispersion is computed for each bin.

### Value

A list with class "codisp" containing the following components:

coef	a vector of size nclass containing the values of the codispersion coefficient.
upper.bounds	upper bounds of the intervals constructed to compute the codispersion coefficient.
card	number of elements in each interval generated to compute the codispersion coefficient.

The function plot can be used to obtain a graph of the codispersion coefficient versus the lag distance.

### References

- Matheron, G. (1965), *Les Variables Regionalisees et leur Estimation*. Masson, Paris.
- Rukhin, A., Vallejos, R. (2008), Codispersion coefficient for spatial and temporal series. *Statistics and Probability Letters* **78**, 1290–1300.
- Vallejos, R. (2008). Assessing the association between two spatial or temporal sequences. *Journal of Applied Statistics* **35**, 1323–1343.

**Examples**

```

# Murray Smelter site dataset
data(murray)

# defining the arsenic (As) and lead (Pb) variables from the murray dataset
x <- murray$As
y <- murray$Pb

# extracting the coordinates from Murray dataset
coords <- murray[c("xpos", "ypos")]

# computing the codispersion coefficient
z <- codisp(x, y, coords)
z

## plotting the codispersion coefficient vs. the lag distance
plot(z)

# Comovement between two time series representing the monthly deaths
# from bronchitis, emphysema and asthma in the UK for 1974-1979
x <- mdeaths
y <- fdeaths
coords <- cbind(1:72, rep(1,72))
z <- codisp(x, y, coords)

# plotting codispersion and cross-correlation functions
par(mfrow = c(1,2))
ccf(x, y, ylab = "cross-correlation", max.lag = 20)
plot(z)

```

---

cor.spatial

*Tjostheim's Coefficient*


---

**Description**

Computes Tjostheim's coefficient for two spatial sequences observed over the same locations on the plane.

**Usage**

```
cor.spatial(x, y, coords)
```

**Arguments**

x	an n-dimensional vector of data values.
y	an n-dimensional vector of data values.
coords	an n-by-2 matrix containing coordinates of the n data locations in each row.

### Details

The implemented technique is a nonparametric coefficient that summarizes the association between two spatial variables. This coefficient was first introduced by Tjostheim (1978) and later generalized by Hubert and Golledge (1992). The computation of the coefficient is based on the construction of ranks associated to suitable modifications of the coordinates. Tjostheim's coefficient is a variant of the correlation coefficient (`cor`) to be used in a spatial statistics context.

### Value

Tjostheim's coefficient. The variance is returned as the attribute "variance".

### References

Tjostheim, D., (1978), A measure of association for spatial variables. *Biometrika* **65**, 109–114.

Hubert, L., Golledge, R.G., (1982), Measuring association between spatially defined variables: Tjostheim's coefficient index and some extensions. *Geographical Analysis* **14**, 273–278.

### Examples

```
# Murray Smelter site dataset
data(murray)

# defining the arsenic (As) and lead (Pb) variables from the murray dataset
x <- murray$As
y <- murray$Pb

# extracting the coordinates from Murray dataset
coords <- murray[c("xpos", "ypos")]

# computing Tjostheim's coefficient
z <- cor.spatial(x, y, coords)
z
```

---

CQ

*Codispersion based similarity index*

---

### Description

This function computes a similarity index (CQ) based on the codispersion coefficient.

### Usage

```
CQ(x, y, h = c(0,1), eps = c(0.01, 0.03), L = 255)
```

**Arguments**

x	reference image matrix (grayscale)
y	distorted image matrix (grayscale)
h	2-dimensional vector of the spatial lag. Default value is $h = c(0, 1)$ .
eps	rescaling constants, by default $eps = c(0.01, 0.03)$
L	dynamic range of the images, by default $L = 255$ .

**Value**

A list containing the following components:

CQ	codispersion based similarity index between images x and y.
direction	vector of spatial lag.
comps	components of CQ, that is luminance, contrast and codispersion
stats	sample statistics (means, variances and covariance) for each image.
speed	Running time taken by the procedure.

**References**

Ojeda, S.M., Lamberti, P.W., Vallejos, R. (2012). Measure of similarity between images based on the codispersion coefficient. *Journal of Electronic Imaging* **21**, 023019.

Vallejos, R., Mancilla, D., Acosta, J. (2016). Image similarity assessment based on coefficients of spatial association. *Journal of Mathematical Imaging and Vision* **56**, 77-98.

**Examples**

```
data(texmos2)

y <- imnoise(texmos2, type = "gaussian")
plot(as.raster(y))
o <- CQ(texmos2, y, h = c(0,1))
o

y <- imnoise(texmos2, type = "speckle")
plot(as.raster(y))
o <- CQ(texmos2, y, h = c(0,1))
o
```

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imnoise	<i>Add noise to image</i>
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**Description**

This function adds noise to an input image.

**Usage**

```
imnoise(img, type = "gaussian", mean = 0, sd = 0.01, epsilon = 0.05, var = 0.04,
        looks = 1, L = 255)
```

**Arguments**

img	input grayscale image matrix.
type	character string, specifying the type of contamination: "gaussian" (Gaussian white/additive noise), "saltnpepper" (salt and pepper noise or on-off noise), "speckle" (uniform multiplicative noise) and "gamma" (gamma multiplicative noise).
mean	mean for the Gaussian noise, default value is mean = 0.
sd	standard deviation for the Gaussian noise, default value is sd = 0.01.
epsilon	contamination percentage for the salt and pepper noise with default noise density 0.05. This affects approximately epsilon% of pixels.
var	variance of uniform multiplicative noise using the equation $noise = img + unif * img$ , with $unif$ is uniformly distributed with mean 0 and variance var. Default value is var = 0.04.
looks	parameter of gamma multiplicative noise. The default value is looks = 1.
L	dynamic range of the images, by default L = 255.

**Value**

Noisy image, returned as a numeric matrix. The imnoise function clips output pixel values to the range [0, 1] after adding noise.

**Examples**

```
data(texmos2)
x <- imnoise(texmos2, type = "saltnpepper", epsilon = 0.10)
plot(as.raster(x))

y <- imnoise(texmos2, type = "speckle")
plot(as.raster(y))

z <- imnoise(texmos2, type = "gamma", looks = 4)
plot(as.raster(z))
```

---

modified.Ftest	<i>Modified F test</i>
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---

### Description

Performs a modified version of the  $F$  test to assess the multiple correlation between one spatial processes and several others.

### Usage

```
modified.Ftest(x, y, coords, nclass = 13)
```

### Arguments

x	an n-by-q matrix of data values.
y	an n-dimensional vector of data values.
coords	an n-by-2 matrix containing coordinates of the n data locations in each row.
nclass	a single number giving the number of cells for Moran's index. The default is 13. If this argument is NULL Sturges' formula is used.

### Details

The methodology implemented is a modified  $F$  test for assessing the multiple correlation between one spatial process and several others. The test is based on corrections of the multiple correlation coefficient between the two spatially correlated sequences and required the estimation of an effective sample size. This factor takes into account the spatial association of both processes.

### Value

A list with class "mod.Ftest" containing the following components:

corr	the sample correlation coefficient.
ESS	the estimated effective sample size.
Fstat	the value of the (unscaled) $F$ -statistic.
df1, df2	degrees of freedom for the $F$ -statistic.
p.value	the $p$ -value for the test.
upper.bounds	upper bounds of the intervals constructed to compute Moran's $I$ .
card	number of elements in each interval generated to compute Moran's $I$ .
imoran	a matrix containing Moran's index for each interval associated with the response and predicted variables.

The generic functions `print` and `summary` are used to obtain and print additional details about the modified  $F$  test.



## References

Dutilleul, P., Pelletier, B., Alpargu, G. (2008). Modified  $F$  tests for assessing the multiple correlation between one spatial process and several others. *Journal of Statistical Planning and Inference* **138**, 1402–1415.

## Examples

```
# The Pinus Radiata data set
data(radiata)

# defining the response and predictor variables from the radiata data set
y <- radiata$height
x <- radiata[c("basal", "altitude", "slope")]

# extracting the coordinates from the radiata data set
coords <- radiata[c("xpos", "ypos")]

# computing the modified F-test of spatial association
z <- modified.Ftest(x, y, coords)
z

# display the upper bounds, cardinality and the computed Moran's index
summary(z)
```

---

modified.ttest	<i>Modified t test</i>
----------------	------------------------

---

## Description

Performs a modified version of the  $t$  test to assess the correlation between two spatial processes.

## Usage

```
modified.ttest(x, y, coords, nclass = 13)
```

## Arguments

x	an n-dimensional vector of data values.
y	an n-dimensional vector of data values.
coords	an n-by-2 matrix containing coordinates of the n data locations in each row.
nclass	a single number giving the number of cells for Moran's index. The default is 13. If this argument is NULL Sturges' formula is used.

## Details

The methodology implemented is a modified  $t$  test of spatial association based on the work of Clifford and Richardson (1989). The test is based on corrections of the sample correlation coefficient between the two spatially correlated sequences and required the estimation of an effective sample size. This factor takes into account the spatial association of both processes.

**Value**

A list with class "mod.ttest" containing the following components:

corr	the sample correlation coefficient.
ESS	the estimated effective sample size.
Fstat	the value of the (unscaled) $F$ -statistic.
dof	the estimated degrees of freedom for the $F$ -statistic.
p.value	the $p$ -value for the test.
upper.bounds	upper bounds of the intervals constructed to compute Moran's $I$ .
card	number of elements in each interval generated to compute Moran's $I$ .
imoran	a matrix containing Moran's index for each interval associated with both variables.

The generic functions `print` and `summary` are used to obtain and print additional details about the modified  $t$  test.

**References**

Clifford, P., Richardson, S., Hemon, D. (1989). Assessing the significance of the correlation between two spatial processes. *Biometrics* **45**, 123–134.

Dutilleul, P. (1993). Modifying the  $t$  test for assessing the correlation between two spatial processes. *Biometrics* **49**, 305–314.

**Examples**

```
# Murray Smelter site dataset
data(murray)

# defining the arsenic (As) and lead (Pb) variables from the murray dataset
x <- murray$As
y <- murray$Pb

# extracting the coordinates from Murray dataset
coords <- murray[c("xpos", "ypos")]

# computing the modified t-test of spatial association
z <- modified.ttest(x, y, coords)
z

# display the upper bounds, cardinality and the computed Moran's index
summary(z)
```

---

`murray`*The Murray smelter site dataset*

---

**Description**

The dataset consists of soil samples collected in and around the vacant, industrially contaminated, Murray smelter site (Utah, USA). This area was polluted by airborne emissions and the disposal of waste slag from the smelting process. A total of 253 locations were included in the study, and soil samples were taken from each location. Each georeferenced sample point is a pool composite of four closely adjacent soil samples in which the concentration of the heavy metals arsenic (As) and lead (Pb) was determined.

**Usage**`data(murray)`**Format**

A data frame with 253 observations on the following 5 variables.

**As** arsenic concentrations measurements.

**Pb** lead concentrations measurements.

**xpos** x-coordinates.

**ypos** y-coordinates.

**quad** a factor where numbers indicate different sub-regions within the area.

**Source**

Griffith, D., Paelinck, J.H.P. (2011). *Non-Standard Spatial Statistics*. Springer, New York.

---

`normalize`*Normalization for a matrix*

---

**Description**

This function normalizes an image matrix so that the minimum value is 0 and the maximum value is 1.

**Usage**`normalize(img)`**Arguments**

`img` target image

**Value**

Image matrix in which minimum value is 0 and maximum value is 1.

**Examples**

```
data(twelve)
x <- RGB2gray(twelve, method = "RMY")
x <- normalize(x)
plot(as.raster(x))
```

---

radiata

*The Pinus Radiata dataset*

---

**Description**

*Pinus radiata* is one of the mostly widely planted species in Chile and is planted in a wide array of soil types and regional climates. The plots were located in the Escuadron sector, south of Concepcion, in the southern portion of Chile and has an area of 1244.43 hectares.

**Usage**

```
data(radiata)
```

**Format**

A data frame with 468 observations on the following 6 variables.

**xpos** x-coordinates.

**ypos** y-coordinates.

**basal** basal area measurements.

**height** dominant tree height.

**altitude** altitude in meters.

**slope** slope of the terrain plot.

**Source**

Cuevas, F., Porcu, E., Vallejos, R. (2013). Study of spatial relationships between two sets of variables: A nonparametric approach. *Journal of Nonparametric Statistics* **25**, 695–714.

Vallejos, R., Osorio, F., Bevilacqua, M. (2019+). *Spatial Relationships Between Two Georeferenced Variables: with Applications in R*. Springer, New York.

---

`RGB2gray`*Convert RGB image or colormap to grayscale image*

---

**Description**

This function converts color image to gray image.

**Usage**

```
RGB2gray(img, method = "average", weights = NULL)
```

**Arguments**

<code>img</code>	target image, specified as an <code>nrow-by-ncol-by-3</code> numeric array.
<code>method</code>	character, procedure for converting color to grayscale. Available methods are "average", "BT240", "brighter" (or maximum decomposition), "darker" (or minimum decomposition), "ITU" (or BT.709), "lightness" (or desaturation), "LUMA" (or BT.601), "RMY" and "weighted" (user provided).
<code>weights</code>	weights for red (R), green (G), and blue (B) channels. Required if <code>method = "weighted"</code> .

**Value**

Grayscale image, returned as an `nrow-by-ncol` numeric matrix with values in the range `[0, 1]`.

`RGB2gray` converts RGB values to grayscale values by forming a weighted sum of the R, G, and B channels.

**Examples**

```
data(twelve)
par(pty = "s", mfrow = c(1,3))
plot(as.raster(twelve)) # in RGB
title(main = "original", font.main = 1)

x <- RGB2gray(twelve, method = "RMY")
plot(as.raster(x)) # in grayscale
title(main = "RMY", font.main = 1)

x <- RGB2gray(twelve, method = "ITU")
plot(as.raster(x)) # OMG! 12 is gone...
title(main = "ITU", font.main = 1)
```

---

 SSIM

*Structural similarity index*


---

### Description

This function computes the structural similarity index (SSIM) proposed by Wang et al. (2004).

### Usage

```
SSIM(x, y, alpha = 1, beta = 1, gamma = 1, eps = c(0.01, 0.03), L = 255)
```

### Arguments

x	reference image matrix (grayscale)
y	distorted image matrix (grayscale)
alpha	weight associated with luminance, default value is alpha = 1.
beta	weight associated with contrast, default value is beta = 1.
gamma	weight associated with structure, default value is gamma = 1.
eps	rescaling constants, by default eps = c(0.01, 0.03)
L	dynamic range of the images, by default L = 255.

### Value

A list containing the following components:

SSIM	structural similarity index between images x and y.
coefficients	weights (alpha, beta, gamma) associated with each component of SSIM
comps	components of SSIM, that is luminance, contrast and structure
stats	sample statistics (means, variances and covariance) for each image.
speed	Running time taken by the procedure.

### References

- Wang, Z., Bovik, A.C. (2002). A universal image quality index. *IEEE Signal Processing Letters* **9**, 81-84.
- Wang, Z., Bovik, A.C., Sheikh, H.R., Simoncelli, E.P. (2004). Image quality assessment: From error visibility to structural similarity. *IEEE Transactions on Image Processing* **13**, 600-612.

**Examples**

```
data(texmos2)

y <- imnoise(texmos2, type = "gaussian")
plot(as.raster(y))
o <- SSIM(texmos2, y)
o

y <- imnoise(texmos2, type = "speckle")
plot(as.raster(y))
o <- SSIM(texmos2, y)
o
```

---

texmos2

*USC texture mosaic number 2*

---

**Description**

Gray-level texture map with information about mosaic composed of eight different texture samples taken from the Brodatz texture book, available from USC-SIPI image database.

**Usage**

```
data(texmos2)
```

**Format**

A grayscale matrix of size 512-by-512.

**Source**

Brodatz, P. (1966). *Textures: A Photographic Album for Artist and Designers*. Dover Publications, New York.

USC-SIPI image database, URL: <http://sipi.usc.edu/database/>

---

twelve

*Ishihara plate number 1*

---

**Description**

Ishihara plate number 1, with the numeral '12' designed to be visible by all persons.

**Usage**

```
data(twelve)
```

**Format**

An array of 380-by-380-by-3 representing a RGB image.

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