Package: fastLISA (via r-universe)

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Type Package

Title Fast Local Indicators of Spatial Association (LISA)

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Description Computes various Local Indicators of Spatial Association (LISA) statistics, including univariate and bivariate local Moran's I, Empirical Bayes local Moran's I, univariate and multivariate local Geary's C, and Getis-Ord G and G* statistics. The methods follow Anselin (1995), Getis and Ord (1992), and Anselin (2019). Leverages a high-performance, plain-C backend with optional 'OpenMP' multi-core support for fast permutation-based pseudo-p-value calculation. Accepts any 'spdep' listw spatial weight matrix, including custom and non-contiguity weights. Uses sample standardisation (n-1) and 'rgeoda'-style permutation p-values. Output cluster codes match 'rgeoda' conventions, including the Isolated category for observations without neighbours.

URL https://github.com/lizhongc/fastLISA

BugReports https://github.com/lizhongc/fastLISA/issues

License GPL-3

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Imports stats

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Contents

local_g 2
local_geary 4
local_gstar 6
local_moran 8
local_moran_bv 9
local_moran_eb 12
local_multigeary 14

Index **17**

`local_g` *Local Getis-Ord G*

Description

`local_g` computes the Getis-Ord local G_i statistic, a Local Indicator of Spatial Association that detects local clustering of high values ("hot spots") and low values ("cold spots"). For observation i, with row-standardised spatial weights w^*_{ij} and the focal value *excluded* from both the lag and the denominator,

$$G_i = \frac{\sum_{j \neq i} w^*_{ij} x_j}{\sum_k x_k - x_i}.$$

A large G_i indicates that i is surrounded by high values; a small G_i indicates a low-value neighbourhood. G_i contains no self term; see `local_gstar` for the self-inclusive G^*_i.

Usage

```
local_g(
  x,
  listw,
  nsim = 999L,
  iseed = NULL,
  p.value = 0.05,
  n.cores = 1L,
  moments = FALSE,
  p.method = c("count", "rank")
)
```

Arguments

`x`	Numeric vector of length `n`.
`listw`	A `listw` object from **spdep**.
`nsim`	Integer; number of permutations. Default `999L`. Must be at least 1.
`iseed`	Integer seed for RNG, or `NULL`.
`p.value`	Numeric significance cutoff. Default `0.05`.

`n.cores` Integer; number of OpenMP threads. Default `1L`; set higher to use multiple cores. Ignored on platforms without OpenMP.

`moments` Logical; if `TRUE`, append permutation-distribution moments `E.Gi`, `Var.Gi`, `Skew.Gi`, and `Kurt.Gi`. Default `FALSE`.

`p.method` Character; how the observed statistic is located within its permutation distribution. `"count"` (default) is the standard rule: it counts the permutations at least as extreme as the observed value, matching the folded pseudo p-value reported by **rgeoda** and **spdep**. `"rank"` is the ties-averaged alternative, using **spdep**'s averaged rank of the observed value. The two differ only when a permuted value exactly ties the observed one (discrete or tie-prone data); both return a folded (smaller-tail) value.

Details

Inference uses a conditional permutation test: the focal value x_i is held fixed while the neighbouring values are randomly permuted `nsim` times. The pseudo p-value is folded (two-tailed),

$$p_i = \frac{\min(g,\ \mathrm{nsim} - g) + 1}{\mathrm{nsim} + 1},$$

where g is the number of permutations with $G_i^{\mathrm{perm}} \geq G_i^{\mathrm{obs}}$. The standardised score is $Z.G_i = (G_i - E_{\mathrm{perm}})/\sqrt{\mathrm{Var}_{\mathrm{perm}}}$, computed from the permutation mean and variance; `Skew.Gi` and `Kurt.Gi` (when `moments = TRUE`) follow the **e1071** type-3 convention.

Observations with a missing `x` value are labelled `Undefined` and observations with no neighbours are labelled `Isolated`; both receive `NA` for the p-value, Z-score and moments. The C backend re-seeds its random number generator per observation, so results are identical for any `n.cores`; `n.cores` is ignored when the package is built without OpenMP.

Value

A numeric matrix of class `c("localG", "matrix", "array")` with columns `Gi`, `Z.Gi`, and `Pr(folded) Sim`. When `moments = TRUE`, the permutation-moment columns are appended. It has the following attributes:

cluster A significance-filtered factor with levels `Not significant`, `High-High`, `Low-Low`, `Undefined` and `Isolated`.

gstari Logical flag set to `FALSE` indicating local G (not G*).

call The matched call.

References

Getis, A. and Ord, J. K. (1992) The Analysis of Spatial Association by Use of Distance Statistics. *Geographical Analysis* **24**(3), 189–206. doi:10.1111/j.15384632.1992.tb00261.x

Ord, J. K. and Getis, A. (1995) Local Spatial Autocorrelation Statistics: Distributional Issues and an Application. *Geographical Analysis* **27**(4), 286–306. doi:10.1111/j.15384632.1995.tb00912.x

Examples

```
lw <- spdep::nb2listw(spdep::cell2nb(7, 7))
x  <- as.numeric(seq_len(49))
res <- local_g(x, lw, nsim = 99L, n.cores = 1L)
head(res)
```

`local_geary` *Univariate Local Geary's C*

Description

`local_geary` computes the univariate local Geary's C_i, a squared-difference Local Indicator of Spatial Association that measures how much a unit differs from its neighbours. On the sample $(n-1)$ standardised variable z (when `scale = TRUE`) with row-standardised weights w^*_{ij},

$$C_i = \sum_j w^*_{ij}(z_i - z_j)^2 = z_i^2 - 2z_i \lag(z)_i + \lag(z^2)_i.$$

A small C_i means i resembles its neighbours (positive spatial association); a large C_i means it differs from them (negative association, a spatial outlier).

Usage

```
local_geary(
  x,
  listw,
  nsim = 999L,
  scale = TRUE,
  iseed = NULL,
  p.value = 0.05,
  n.cores = 1L,
  moments = FALSE,
  p.method = c("count", "rank")
)
```

Arguments

`x`	Numeric vector of length `n`.
`listw`	A `listw` object from **spdep**.
`nsim`	Integer; number of permutations. Default `999L`. Must be at least 1.
`scale`	Logical; if `TRUE` (default), standardise data in R.
`iseed`	Integer seed for RNG, or `NULL`.
`p.value`	Numeric significance cutoff. Default `0.05`.
`n.cores`	Integer; number of OpenMP threads. Default `1L`; set higher to use multiple cores. Ignored on platforms without OpenMP.

`moments` Logical; if `TRUE`, append permutation-distribution moments `E.Ci`, `Var.Ci`, `Skew.Ci`, and `Kurt.Ci`. Default `FALSE`.

`p.method` Character; how the observed statistic is located within its permutation distribution. `"count"` (default) is the standard rule: it counts the permutations at least as extreme as the observed value, matching the folded pseudo p-value reported by **rgeoda** and **spdep**. `"rank"` is the ties-averaged alternative, using **spdep**'s averaged rank of the observed value. The two differ only when a permuted value exactly ties the observed one (discrete or tie-prone data); both return a folded (smaller-tail) value.

Details

Inference uses a one-tailed conditional permutation test (`nsim` reps): the observed C_i is compared with the permutation mean to select the tail, and

$$p_i = \frac{t+1}{\mathrm{nsim}+1},$$

where t counts permuted statistics in that tail. The standardised score is $Z.C_i = (C_i - E_{\mathrm{perm}})/\sqrt{\mathrm{Var}_{\mathrm{perm}}}$; `Skew.Ci`/`Kurt.Ci` (when `moments = TRUE`) follow the **e1071** type-3 convention. The `cluster` factor splits significant positive association into `High-High`/`Low-Low`/`Other Positive` and labels significant dissimilarity `Negative`.

Observations with a missing `x` value are labelled `Undefined` and observations with no neighbours are labelled `Isolated`; both receive `NA` for the p-value, Z-score and moments. The C backend re-seeds its random number generator per observation, so results are identical for any `n.cores`; `n.cores` is ignored when the package is built without OpenMP.

Value

A numeric matrix of class `c("localC", "matrix", "array")` with columns `Ci`, `Z.Ci`, and `Pr Sim`. When `moments = TRUE`, the permutation-moment columns are appended. It has the following attributes:

cluster A significance-filtered factor with levels Not significant, High-High, Low-Low, Other Positive, Negative, Undefined, and Isolated.

call The matched call.

References

Anselin, L. (1995) Local Indicators of Spatial Association—LISA. *Geographical Analysis* **27**(2), 93–115. doi:10.1111/j.15384632.1995.tb00338.x

Examples

```
lw <- spdep::nb2listw(spdep::cell2nb(7, 7))
x  <- as.numeric(seq_len(49))
res <- local_geary(x, lw, nsim = 99L, n.cores = 1L)
head(res)
```

`local_gstar` *Local Getis-Ord G**

Description

`local_gstar` computes the Getis-Ord local G_i^* statistic, the self-inclusive companion of `local_g`: observation i is treated as its own neighbour (weight 1). With m_i valid neighbours, row-standardised neighbour weights w_{ij}, and global total $S = \sum_k x_k$,

$$G_i^* = \frac{\left(\frac{\sum_{j \in N_i} w_{ij} x_j}{\sum_j w_{ij}}\right) m_i + x_i}{(m_i + 1)\, S},$$

i.e. the average value over the focal unit and its neighbours divided by the global sum. Large G_i^* flags a hot spot and small G_i^* a cold spot, with the focal unit included.

Usage

```
local_gstar(
  x,
  listw,
  nsim = 999L,
  iseed = NULL,
  p.value = 0.05,
  n.cores = 1L,
  moments = FALSE,
  p.method = c("count", "rank")
)
```

Arguments

`x`	Numeric vector of length `n`.
`listw`	A `listw` object from **spdep**.
`nsim`	Integer; number of permutations. Default `999L`. Must be at least 1.
`iseed`	Integer seed for RNG, or `NULL`.
`p.value`	Numeric significance cutoff. Default `0.05`.
`n.cores`	Integer; number of OpenMP threads. Default `1L`; set higher to use multiple cores. Ignored on platforms without OpenMP.
`moments`	Logical; if `TRUE`, append permutation-distribution moments `E.G*i`, `Var.G*i`, `Skew.G*i`, and `Kurt.G*i`. Default `FALSE`.
`p.method`	Character; how the observed statistic is located within its permutation distribution. `"count"` (default) is the standard rule: it counts the permutations at least as extreme as the observed value, matching the folded pseudo p-value reported by **rgeoda** and **spdep**. `"rank"` is the ties-averaged alternative, using **spdep**'s averaged rank of the observed value. The two differ only when a permuted value exactly ties the observed one (discrete or tie-prone data); both return a folded (smaller-tail) value.

Details

Inference uses a conditional permutation test (`nsim` reps), with the focal x_i held fixed while neighbour values are permuted. The pseudo p-value is folded (two-tailed),

$$p_i = \frac{\min(g,\ \mathrm{nsim} - g) + 1}{\mathrm{nsim} + 1},$$

where g counts permutations with $G_i^{*\,\mathrm{perm}} \geq G_i^{*\,\mathrm{obs}}$. The standardised score $Z.G_i^* = (G_i^* - E_{\mathrm{perm}})/\sqrt{\mathrm{Var}_{\mathrm{perm}}}$ uses the permutation moments; `Skew.G*i`/`Kurt.G*i` (when `moments = TRUE`) follow the **e1071** type-3 convention.

Observations with a missing `x` value are labelled `Undefined` and observations with no neighbours are labelled `Isolated`; both receive `NA` for the p-value, Z-score and moments. The C backend re-seeds its random number generator per observation, so results are identical for any `n.cores`; `n.cores` is ignored when the package is built without OpenMP.

Value

A numeric matrix of class `c("localG", "matrix", "array")` with columns `G*i`, `Z.G*i`, and `Pr(folded) Sim`. When `moments = TRUE`, the permutation-moment columns are appended. It has the following attributes:

cluster A significance-filtered factor with levels `Not significant`, `High-High`, `Low-Low`, `Undefined` and `Isolated`.

gstari Logical flag set to `TRUE` indicating local G*.

call The matched call.

References

Getis, A. and Ord, J. K. (1992) The Analysis of Spatial Association by Use of Distance Statistics. *Geographical Analysis* **24**(3), 189–206. doi:10.1111/j.15384632.1992.tb00261.x

Ord, J. K. and Getis, A. (1995) Local Spatial Autocorrelation Statistics: Distributional Issues and an Application. *Geographical Analysis* **27**(4), 286–306. doi:10.1111/j.15384632.1995.tb00912.x

Examples

```
lw <- spdep::nb2listw(spdep::cell2nb(7, 7))
x  <- as.numeric(seq_len(49))
res <- local_gstar(x, lw, nsim = 99L, n.cores = 1L)
head(res)
```

`local_moran` *Univariate Local Moran's I*

Description

`local_moran` computes the univariate local Moran's I_i, the classic Local Indicator of Spatial Association measuring whether a value coincides with its neighbours' average. On the sample $(n-1)$ standardised variable z with row-standardised weights w^*_{ij},

$$I_i = z_i \sum_j w^*_{ij} z_j = z_i \, \mathrm{lag}(z)_i.$$

A positive I_i indicates similarity to neighbours (a High-High or Low-Low cluster); a negative I_i indicates a spatial outlier (High-Low or Low-High). Standardisation uses the sample standard deviation ($n-1$ denominator).

Usage

```
local_moran(
  x,
  listw,
  nsim = 999L,
  iseed = NULL,
  p.value = 0.05,
  n.cores = 1L,
  moments = FALSE,
  p.method = c("count", "rank")
)
```

Arguments

`x`	Numeric vector of length `n`.
`listw`	A `listw` object from **spdep**.
`nsim`	Integer; number of permutations. Default `999L`. Must be at least 1.
`iseed`	Integer seed for RNG, or `NULL`.
`p.value`	Numeric significance cutoff. Default `0.05`.
`n.cores`	Integer; number of OpenMP threads. Default `1L`; set higher to use multiple cores. Ignored on platforms without OpenMP.
`moments`	Logical; if `TRUE`, append the permutation-distribution moments `E.Ii`, `Var.Ii`, `Skew.Ii`, and `Kurt.Ii` to the result matrix. Default `FALSE`.
`p.method`	Character; how the observed statistic is located within its permutation distribution. `"count"` (default) is the standard rule: it counts the permutations at least as extreme as the observed value, matching the folded pseudo p-value reported by **rgeoda** and **spdep**. `"rank"` is the ties-averaged alternative, using **spdep**'s averaged rank of the observed value. The two differ only when a permuted value exactly ties the observed one (discrete or tie-prone data); both return a folded (smaller-tail) value.

Details

This is the $x = y$ special case of bivariate local Moran's I, so the computation delegates to `local_moran_bv` (with `scale = TRUE`) and relabels the columns. Inference uses a conditional permutation test (`nsim` reps) with the folded two-tailed pseudo p-value $p_i = (\min(g, \text{nsim} - g) + 1)/(\text{nsim} + 1)$, where g is the number of permutations with $I^{\text{perm}} \geq I^{\text{obs}}$. The standardised score is $Z.I_i = (I_i - E_{\text{perm}})/\sqrt{\text{Var}_{\text{perm}}}$ and `Skew.Ii`/`Kurt.Ii` (when `moments = TRUE`) use the **e1071** type-3 convention. NA observations are `Undefined` and neighbourless observations are `Isolated` (both `NA` in p-value, Z-score and moments). The C backend re-seeds its random number generator per observation, so results are identical for any `n.cores`.

Value

A numeric matrix of class `c("localmoran", "matrix", "array")` with `n` rows and 3 columns by default:

Ii Observed univariate Moran statistic.

Z.Ii Standardised Z-score computed from permutation moments.

Pr(folded) Sim rgeoda-style folded empirical permutation p-value.

When `moments = TRUE`, the permutation-distribution columns `E.Ii`, `Var.Ii`, `Skew.Ii`, and `Kurt.Ii` are appended. The matrix has the following attributes:

quadr Moran scatter-plot quadrant classification.

cluster A significance-filtered factor with levels `Not significant`, `High-High`, `Low-Low`, `Low-High`, `High-Low`, `Undefined` and `Isolated`.

References

Anselin, L. (1995) Local Indicators of Spatial Association—LISA. *Geographical Analysis* **27**(2), 93–115. doi:10.1111/j.15384632.1995.tb00338.x

Examples

```
lw <- spdep::nb2listw(spdep::cell2nb(7, 7))
x  <- as.numeric(seq_len(49))
res <- local_moran(x, lw, nsim = 99L, n.cores = 1L, moments = TRUE)
head(res)
```

`local_moran_bv` *Bivariate Local Moran's I*

Description

`local_moran_bv` computes the bivariate local Moran's $I_{bv,i}$, which correlates a variable x at i with the spatial lag of a second variable y over i's neighbours. On the sample $(n-1)$ standardised variables z_x, z_y (when `scale = TRUE`) with row-standardised weights w^*_{ij},

$$I_{bv,i} = z_{x,i} \sum_j w^*_{ij} z_{y,j} = z_{x,i} \, \mathrm{lag}(z_y)_i.$$

A positive $I_{bv,i}$ means i's x value coincides with high lagged y nearby; a negative value indicates spatial mismatch. The univariate local Moran's I is the special case $x = y$ (see `local_moran`). The backend is plain C with optional OpenMP parallelism.

Usage

```
local_moran_bv(
  x,
  y,
  listw,
  nsim = 999L,
  scale = TRUE,
  iseed = NULL,
  p.value = 0.05,
  n.cores = 1L,
  moments = FALSE,
  p.method = c("count", "rank")
)
```

Arguments

`x`	Numeric vector of length `n`; the first variable.
`y`	Numeric vector of length `n`; the second variable (lagged).
`listw`	A `listw` object from **spdep** (any style: "W", "B", "C", etc., including custom distance-decay weights). Observations with no neighbours receive cluster code 6 (Isolated).
`nsim`	Integer; number of permutations for the pseudo p-value. Default `999L`.
`scale`	Logical; if `TRUE` (default), `x` and `y` are standardised in R (sample std dev). Set to `FALSE` only if you have pre-standardised the data.
`iseed`	Integer seed for the RNG, or `NULL` (default) to use the package default (123456789). Passed as the `seed` argument to the C backend.
`p.value`	Numeric; observations with $p >$ p.value are recoded to cluster 0 (Not significant). Default `0.05`.
`n.cores`	Integer; number of OpenMP threads. Default `1L`; set higher to use multiple cores. Ignored on platforms without OpenMP.
`moments`	Logical; if `TRUE`, append the permutation-distribution moments `E.Ibvi`, `Var.Ibvi`, `Skew.Ibvi`, and `Kurt.Ibvi` to the result matrix. Default `FALSE`.

`p.method` Character; how the observed statistic is located within its permutation distribution. `"count"` (default) is the standard rule: it counts the permutations at least as extreme as the observed value, matching the folded pseudo p-value reported by **rgeoda** and **spdep**. `"rank"` is the ties-averaged alternative, using **spdep**'s averaged rank of the observed value. The two differ only when a permuted value exactly ties the observed one (discrete or tie-prone data); both return a folded (smaller-tail) value.

Details

Inference uses a conditional permutation test (`nsim` reps): the neighbour y-values are permuted with the focal observation held fixed. See the *P-values* and *Cluster codes* sections below for the folded p-value and the cluster coding. The standardised score is $Z.I_{bv,i} = (I_{bv,i} - E_{\text{perm}})/\sqrt{\text{Var}_{\text{perm}}}$; `Skew.Ibvi`/`Kurt.Ibvi` (when `moments = TRUE`) follow the **e1071** type-3 convention. NA observations are `Undefined` and neighbourless observations are `Isolated` (both `NA` in p-value, Z-score and moments). The C backend re-seeds its random number generator per observation, so results are identical for any `n.cores`.

Value

A numeric matrix of class `c("localmoran", "matrix", "array")` with `n` rows and 3 columns by default:

Ibvi Observed bivariate Moran statistic.

Z.Ibvi Standardised Z-score computed from permutation moments.

Pr(folded) Sim rgeoda-style folded empirical permutation p-value.

When `moments = TRUE`, the permutation-distribution columns `E.Ibvi`, `Var.Ibvi`, `Skew.Ibvi`, and `Kurt.Ibvi` are appended. The matrix has the following attributes:

quadr A `data.frame` with three factor columns (`mean`, `median`, `pysal`) giving the Moran scatterplot quadrant for each observation, computed on the original (unscaled) data scale.

cluster A `factor` representing cluster classification (Not significant, High-High, Low-Low, Low-High, High-Low, Undefined, Isolated).

call The matched call.

Standardisation

Both `x` and `y` are standardised using the **sample** standard deviation ($n-1$ denominator) in R before computing the statistic, consistent with the blisa backend.

P-values

Permutation p-values use the folded two-tailed formula matching rgeoda:

$$p = (\min(\#\{perm \geq obs\},\ \#\{perm < obs\}) + 1) \,/\, (nsim + 1)$$

No normal approximation is computed.

Cluster codes

The returned `cluster` factor attribute is based on integer codes 0–6:

0	Not significant
1	High-High
2	Low-Low
3	Low-High
4	High-Low
5	Undefined (NA input)
6	Isolated (no neighbours)

Codes 5 and 6 are preserved regardless of the significance cutoff.

References

Anselin, L. (1995) Local Indicators of Spatial Association—LISA. *Geographical Analysis* **27**(2), 93–115. doi:10.1111/j.15384632.1995.tb00338.x

Examples

```
lw  <- spdep::nb2listw(spdep::cell2nb(7, 7))
x   <- as.numeric(seq_len(49))
y   <- rev(x)
res <- local_moran_bv(x, y, lw, nsim = 99L, n.cores = 1L, moments = TRUE)
head(res)
attr(res, "quadr")
```

`local_moran_eb` *Local Moran's I with Empirical Bayes (EB) Rate*

Description

`local_moran_eb` computes local Moran's I on Empirical Bayes (EB) variance-stabilised rates, for event-count data observed over a population at risk. Raw rates $p_i = \mathrm{event}_i/\mathrm{base}_i$ from small populations are noisy; EB standardisation shrinks them toward the global rate $b = \sum \mathrm{event}/\sum \mathrm{base}$ using a variance component $\hat{a}$,

$$z_i = \frac{p_i - b}{\sqrt{\hat{a} + b/\mathrm{base}_i}},$$

and local Moran's I is then computed on z. This follows the GeoDa/libgeoda EBLocalMoran formulation.

Usage

```
local_moran_eb(
  event,
  base,
  listw,
  nsim = 999L,
  iseed = NULL,
  p.value = 0.05,
  n.cores = 1L,
  moments = FALSE,
  p.method = c("count", "rank")
)
```

Arguments

event	Numeric vector of events (e.g. case counts).
base	Numeric vector of populations at risk.
listw	A listw object from **spdep**.
nsim	Integer; number of permutations. Default 999L. Must be at least 1.
iseed	Integer seed for RNG, or NULL.
p.value	Numeric significance cutoff. Default 0.05.
n.cores	Integer; number of OpenMP threads. Default 1L; set higher to use multiple cores. Ignored on platforms without OpenMP.
moments	Logical; if TRUE, append the permutation-distribution moments E.Ii, Var.Ii, Skew.Ii, and Kurt.Ii to the result matrix. Default FALSE.
p.method	Character; how the observed statistic is located within its permutation distribution. "count" (default) is the standard rule: it counts the permutations at least as extreme as the observed value, matching the folded pseudo p-value reported by **rgeoda** and **spdep**. "rank" is the ties-averaged alternative, using **spdep**'s averaged rank of the observed value. The two differ only when a permuted value exactly ties the observed one (discrete or tie-prone data); both return a folded (smaller-tail) value.

Details

Two standardisations are applied and are not redundant: the EB rate standardisation above stabilises the rate variance, and the usual sample $(n-1)$ z-score standardisation that local Moran's I requires is then applied to the EB rates internally. Because univariate Moran's I on a standardised variable equals the bivariate statistic with $x = y$, the permutation engine is reused via local_moran_bv. Inference is a conditional permutation test (nsim reps); the folded two-tailed pseudo p-value and the score $Z.I_i = (I_i - E_{\text{perm}})/\sqrt{\text{Var}_{\text{perm}}}$ are as in local_moran, and Skew.Ii/Kurt.Ii (when moments = TRUE) use the **e1071** type-3 convention.

Observations with NA event/base or base ≤ 0 are labelled Undefined; observations with no neighbours are Isolated; both receive NA for the p-value, Z-score and moments. The C backend re-seeds its random number generator per observation, so results are identical for any n.cores.

Value

A numeric matrix of class `c("local_moran_eb", "matrix")` with `n` rows and 3 columns by default:

Ii Observed Local Moran statistic computed on EB-standardised rates.

Z.Ii Standardised Z-score computed from permutation moments.

Pr(folded) Sim Folded empirical permutation p-value.

When `moments = TRUE`, the permutation-distribution columns `E.Ii`, `Var.Ii`, `Skew.Ii`, and `Kurt.Ii` are appended. The matrix has the following attributes:

quadr Moran scatter-plot quadrant classification.

cluster A significance-filtered factor with levels `Not significant`, `High-High`, `Low-Low`, `Low-High`, `High-Low`, `Undefined` and `Isolated`.

call The matched call.

nsim Number of simulations used.

References

Assunção, R. M. and Reis, E. A. (1999) A new proposal to adjust Moran's I for population density. *Statistics in Medicine* **18**(16), 2147–2162. doi:10.1002/(SICI)10970258(19990830)18:16<2147::AID-SIM179>3.0.CO;2I

Anselin, L. (1995) Local Indicators of Spatial Association—LISA. *Geographical Analysis* **27**(2), 93–115. doi:10.1111/j.15384632.1995.tb00338.x

Examples

```
lw    <- spdep::nb2listw(spdep::cell2nb(7, 7))
event <- as.numeric(seq_len(49))
base  <- rep(100, 49)
res <- local_moran_eb(event, base, lw, nsim = 99L, n.cores = 1L)
head(res)
```

`local_multigeary` *Multivariate Local Geary's C*

Description

`local_multigeary` computes the multivariate local Geary's C_i (Anselin 2019), the average across K variables of the univariate squared-difference statistic. On the sample $(n-1)$ standardised variables $z^1, \ldots, z^K$ (when `scale = TRUE`) with row-standardised weights w^*_{ij},

$$C_i = \frac{1}{K} \sum_{v=1}^{K} \sum_{j} w^*_{ij} (z^v_i - z^v_j)^2.$$

A small C_i indicates that i is similar to its neighbours across all variables (positive association); a large C_i indicates multivariate dissimilarity (a spatial outlier).

Usage

```
local_multigeary(
  df,
  listw,
  nsim = 999L,
  scale = TRUE,
  iseed = NULL,
  p.value = 0.05,
  n.cores = 1L,
  moments = FALSE,
  p.method = c("count", "rank")
)
```

Arguments

df	A data.frame or matrix with selected variables.
listw	A listw object from **spdep**.
nsim	Integer; number of permutations. Default 999L. Must be at least 1.
scale	Logical; if TRUE (default), standardise each variable in R.
iseed	Integer seed for RNG, or NULL.
p.value	Numeric significance cutoff. Default 0.05.
n.cores	Integer; number of OpenMP threads. Default 1L; set higher to use multiple cores. Ignored on platforms without OpenMP.
moments	Logical; if TRUE, append permutation-distribution moments E.Ci, Var.Ci, Skew.Ci, and Kurt.Ci. Default FALSE.
p.method	Character; how the observed statistic is located within its permutation distribution. "count" (default) is the standard rule: it counts the permutations at least as extreme as the observed value, matching the folded pseudo p-value reported by **rgeoda** and **spdep**. "rank" is the ties-averaged alternative, using **spdep**'s averaged rank of the observed value. The two differ only when a permuted value exactly ties the observed one (discrete or tie-prone data); both return a folded (smaller-tail) value.

Details

Inference uses a one-tailed conditional permutation test (nsim reps); each replicate applies the same permuted neighbour configuration to every variable. The observed C_i is compared with the permutation mean to choose the tail, and $p_i = (t+1)/(\mathrm{nsim}+1)$, where t counts permuted statistics in that tail. The standardised score is $Z.C_i = (C_i - E_{\mathrm{perm}})/\sqrt{\mathrm{Var}_{\mathrm{perm}}}$; Skew.Ci/Kurt.Ci (when moments = TRUE) follow the **e1071** type-3 convention. Significant units are labelled Positive (similar) or Negative (dissimilar).

Rows with any missing value are labelled Undefined and observations with no neighbours are labelled Isolated; both receive NA for the p-value, Z-score and moments. The C backend re-seeds its random number generator per observation, so results are identical for any n.cores; n.cores is ignored when the package is built without OpenMP.

Value

A numeric matrix of class `c("localC", "matrix", "array")` with columns `Ci`, `Z.Ci`, and `Pr Sim`. When `moments = TRUE`, the permutation-moment columns are appended. It has the following attributes:

cluster A significance-filtered factor with levels Not significant, Positive, Negative, Undefined, and Isolated.

call The matched call.

References

Anselin, L. (2019) A Local Indicator of Multivariate Spatial Association: Extending Geary's c. *Geographical Analysis* **51**(2), 133–150. doi:10.1111/gean.12164

Examples

```
lw <- spdep::nb2listw(spdep::cell2nb(7, 7))
x  <- as.numeric(seq_len(49))
df <- cbind(x, rev(x))
res <- local_multigeary(df, lw, nsim = 99L, n.cores = 1L)
head(res)
```

Index

local_g, 2, *6*
local_geary, 4
local_gstar, *2*, 6
local_moran, 8, *10*, *13*
local_moran_bv, 9, *9*, *13*
local_moran_eb, 12
local_multigeary, 14