

Package: locdiff (via r-universe)

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Type Package

Title Local Diffusion Exponent

Version 1.4

Maintainer Chun-Xiao Nie <niechunxiao2009@163.com>

Description The local diffusion exponent for undirected, unweighted networks characterizes the speed of local diffusion from a specified node and depends on the resistance distance.

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Depends igraph, MASS

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NeedsCompilation no

Author Chun-Xiao Nie [aut, cre] (ORCID:
<<https://orcid.org/0000-0002-7790-0803>>)

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adaptivelocaldiffexp *Compute local diffusion exponents with adaptive fitting range*

Description

For each node, the mean squared resistance displacement is computed exactly via transition matrix powers. Then, for a fixed starting time t_{\min} , we try all possible end times t_{\max} from $t_{\max_{\min}}$ to $t_{\max_{\max}}$, perform a log-log linear regression, and select the t_{\max} that maximizes the coefficient of determination (R^2). The corresponding H_i is returned.

Usage

```
adaptivelocaldiffexp(adj, max_time, t_min, t_max_min, t_max_max)
```

Arguments

adj	Symmetric adjacency matrix (0/1, no self-loops) of a connected graph.
max_time	Maximum number of steps ($t = 1, \dots, \text{max_time}$) for MSD calculation.
t_min	Fixed starting time for fitting (≥ 1).
t_max_min	Minimum end time to try (must be $\geq t_{\min} + 2$ to have at least 3 points).
t_max_max	Maximum end time to try (must be $\leq \text{max_time}$).

Value

A list with components:

H	Numeric vector of length n , estimated local diffusion exponents.
best_R2	Numeric vector of length n , the best R^2 achieved.
best_tmax	Integer vector of length n , the t_{\max} that gave the best R^2 .
msd	Matrix of size $\text{max_time} \times n$, where rows are times $1:\text{max_time}$ and columns are nodes.
fit_objects	List of lm objects for the best fit (one per node).

References

Nie, Chun-Xiao. "Vertex-level diffusion scaling from resistance distance." *Chaos*, Under Review.

Examples

```
# Path graph with 4 nodes
adj <- matrix(c(0,1,0,0,
               1,0,1,0,
               0,1,0,1,
               0,0,1,0), nrow=4, byrow=TRUE)
res <- adaptivelocaldiffexp(adj, max_time = 50,
                           t_min = 10, t_max_min = 20, t_max_max = 40)
print(res$H)
```

exactlocaldiffexp	<i>Compute local diffusion exponents for all nodes using exact analytical method</i>
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Description

For each node i , the mean squared resistance displacement is computed exactly via the transition matrix powers: $MSD_i(t)$, for $t = 1, 2, \dots, \text{max_time}$. Then a log-log linear regression is performed over the specified time window to estimate the local diffusion exponent H_i .

Usage

```
exactlocaldiffexp(adj, max_time, fit_range)
```

Arguments

adj	Symmetric adjacency matrix (0/1, no self-loops) of a connected graph.
max_time	Maximum number of steps (starting from $t=1$).
fit_range	Numeric vector of length 2, e.g. $c(t_min, t_max)$, specifying the time window for fitting ($1 \leq t_min < t_max \leq \text{max_time}$).

Value

A list with components:

H	Numeric vector of length n , the estimated local diffusion exponents.
msd	Matrix of size $\text{max_time} \times n$, where rows correspond to times $1:\text{max_time}$ and columns correspond to nodes. Entry $[t, i] = MSD_i(t)$.
fit	List of lm objects (one per node), or NULL if fit failed.

References

Nie, Chun-Xiao. "Vertex-level diffusion scaling from resistance distance." .Chaos, Under Review.

Examples

```
# Example: path graph with 4 nodes
adj <- matrix(c(0,1,0,0,
               1,0,1,0,
               0,1,0,1,
               0,0,1,0), nrow=4, byrow=TRUE)
res <- exactlocaldiffexp(adj, max_time = 50, fit_range = c(10, 40))
print(res$H)
```

 generalized_sierpinski

Generalized Sierpiński graph

Description

Constructs the generalized Sierpiński graph $S(n, G)$ as defined in "Generalized Sierpiński graphs" (Gravier et al.). The vertex set is $\{1, \dots, k\}^n$ where $k = |V(G)|$, and edges are defined recursively based on the edges of G .

Usage

```
generalized_sierpinski(G, n)
```

Arguments

<code>G</code>	An igraph object representing the base graph. Its vertices must be labelled 1, 2, ..., k (as characters or integers).
<code>n</code>	Integer, dimension ($n \geq 1$). <code>n = 1</code> returns <code>G</code> .

Value

An igraph object representing $S(n, G)$.

References

Gravier, Sylvain, Matjaž Kovše, and Aline Parreau. "Generalized Sierpiński graphs." Posters at EuroComb 11 (2011): 2016-0216.

Examples

```
library(igraph)

# Example 1: Base graph is a 4-cycle
G <- make_ring(4)
S2 <- generalized_sierpinski(G, 2)
plot(S2, vertex.size = 8, vertex.label = NA)

# Example 2: Base graph is a triangle (classical Sierpiński gasket)
G_tri <- make_graph(~ 1-2-3-1)
S3_tri <- generalized_sierpinski(G_tri, 3)
summary(S3_tri) # vertices: 27, edges: 63

# Example 3: Base graph is a complete graph K4
G_K4 <- make_full_graph(4)
S2_K4 <- generalized_sierpinski(G_K4, 2)
summary(S2_K4) # vertices: 16, edges: 96
```

localdiffexp	<i>Compute the local diffusion exponent for a given starting node</i>
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Description

Simulates random walks from a specified node on a graph and estimates the local diffusion exponent from the scaling of the mean squared resistance distance.

Usage

```
localdiffexp(
  R,
  start_node,
  adj,
  fit_range,
  num_paths = 100,
  max_time = 100,
  seed = NULL
)
```

Arguments

R	Resistance distance matrix (symmetric, zero diagonal).
start_node	Index or name of the starting node (must match row/column names of R).
adj	Adjacency matrix (symmetric, 0/1, zero diagonal).
fit_range	Numeric vector of length 2 specifying the time range for fitting, e.g. c(t_start, t_end) with $1 \leq t_start < t_end \leq \max_time$.
num_paths	Number of random walk paths to simulate. Default 100.
max_time	Maximum number of steps (from 0 to max_time). Default 100.
seed	Optional random seed for reproducibility.

Value

A list containing:

H	Estimated local diffusion exponent $\langle H_i \rangle$.
msd	Data frame with columns t (time) and msd (mean squared resistance distance).
fit	lm object from the log-log fit.
paths	Matrix of resistance distances for each path (rows = time steps, columns = paths).

References

Nie, Chun-Xiao. "Vertex-level diffusion scaling from resistance distance." *Chaos*, Under Review.

Examples

```
g<-make_lattice(length = 6, dim = 2)
adj <- as_adjacency_matrix(g,sparse = FALSE)
R <- resistance_distance_matrix(adj)
res <- localdiffexp(R, start_node = 1, adj = adj,fit_range = c(3, 30), max_time = 30)
print(res$H)
```

renyiindex

Compute Rényi's index for a wealth vector

Description

Compute Rényi's index for a wealth vector

Usage

```
renyiindex(w, alpha)
```

Arguments

w Numeric vector of wealth values (non-negative, at least one positive).
alpha Positive parameter controlling the sensitivity of the index.

Value

The Rényi index, a number between 0 and 1.

References

Eliazar, Iddo. "Randomness, evenness, and Rényi's index." *Physica A: Statistical Mechanics and its Applications* 390.11 (2011): 1982-1990.

Examples

```
renyiindex(runif(100,0.1,1), 2)
```

`resistance_distance_matrix`*Compute the resistance distance matrix of a connected undirected graph*

Description

For a connected undirected graph, the resistance distance between two vertices is defined as the effective resistance when each edge is replaced by a unit resistor. It can be computed from the Moore–Penrose pseudoinverse of the graph Laplacian.

Usage

```
resistance_distance_matrix(adj_matrix)
```

Arguments

`adj_matrix` A symmetric adjacency matrix (0/1, no self-loops) representing a connected undirected graph.

Value

A symmetric matrix R where $R[i, j]$ is the resistance distance between vertices i and j . Diagonal entries are 0.

References

D.J.Klein and M.Randic, "Resistance distance," Journal of Mathematical Chemistry 12, 81–95 (1993).

Examples

```
# Example: a path graph with 3 vertices
adj <- matrix(c(0,1,0,
               1,0,1,
               0,1,0), nrow = 3, byrow = TRUE)
R <- resistance_distance_matrix(adj)
print(R)
```

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