

# Package ‘HCD’

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**Type** Package

**Title** Hierarchical Community Detection by Recursive Partitioning

**Version** 1.0

**Date** 2024-01-28

**Description** Hierarchical community detection on networks by a recursive spectral partitioning strategy, which is shown to be effective and efficient in Li, Lei, Bhattacharyya, Sarkar, Bickel, and Levina (2018) <[doi:10.48550/arXiv.1810.01509](https://doi.org/10.48550/arXiv.1810.01509)>. The package also includes a data generating function for a binary tree stochastic block model, a special case of stochastic block model that admits hierarchy between communities.

**License** GPL (>= 2)

**Imports** Matrix, stats, methods, randnet, RSpecra, irlba, data.tree, data.table, stringr, dendextend

**NeedsCompilation** no

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HCD-package

*Hierarchical community detection by recursive partitioning*

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### Description

The package provides the implementation of the recursive partitioning strategy to clustering network nodes in a hierarchical way. It also includes the mechanism of generating networks from a binary tree stochastic block model.

### Details

Package: HCD  
Type: Package  
Version: 1.0  
Date: 2024-01-28  
License: GPL (>= 2)

### Author(s)

Tianxi Li, Lihua Lei, Sharmodeep Bhattacharyya, Purnamrita Sarkar, Peter Bickel, and Elizaveta Levina.

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### References

Li, T., Lei, L., Bhattacharyya, S., Van den Berge, K., Sarkar, P., Bickel, P.J. and Levina, E., 2022. Hierarchical community detection by recursive partitioning. *Journal of the American Statistical Association*, 117(538), pp.951-968.

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BTSBM

*Generates networks from binary tree stochastic block model*

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### Description

Generates networks from binary tree stochastic block model, with provided sequence of connection probability along the tree

### Usage

BTSBM(n, d, a.seq, lambda, alpha = NULL, N = 1)

**Arguments**

n	number of nodes in the network
d	number of layers until leaves (excluding the root)
a.seq	the connection probability sequence along the tree, a_r, see details in the paper
lambda	average node degree, only used when alpha is not provided
alpha	the common scaling of the a_r sequence. So at the end, essentially the a_r sequence is a.seq*alpha
N	the number of networks to generate from the same model

**Value**

A list of objects of

A.list	the generated network adjacency matrices
B	the connection probability matrix between K communities, where $K = 2^d$
label	the vector of community labels for n nodes
P	the connection probability matrix between the n nodes. It is the expectation of adjacency matrices, except on the diagonal
comm.sim.mat	the binary string similarity matrix between communities
node.sim.mat	the binary string similarity matrix between nodes

**Author(s)**

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**Examples**

```
dt <- BTSBM(n=1600, d=4, a.seq=0.2^seq(0, 4), lambda=50)
A <- dt$A.list[[1]]
```

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gen.A.from.P                      *generates a network from the given connection probability*

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### Description

Generates an adjacency matrix from a given probability matrix, according independent Bernoulli – the so-called inhomogeneous Erdos-Renyi model. It is used to generate new networks from a given model.

### Usage

```
gen.A.from.P(P, undirected = TRUE)
```

### Arguments

P	connection probability between nodes
undirected	logic value. FALSE (default) if the network is undirected, so the adjacency matrix will be symmetric with only upper diagonal entries being generated as independent Bernoulli.

### Value

An adjacency matrix

### Author(s)

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### References

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HCD

*hierarchical community detection with recursive spectral methods***Description**

Hierarchical community by recursive spectral partitioning. It includes the splitting methods of spectral clustering and sign splitting, as well stopping rules for fixed stopping, non-backtracking matrix checking and edge cross-validation.

**Usage**

```
HCD(A, method = "SS", stopping = "NB", reg = FALSE, n.min = 25, D = NULL, notree=TRUE)
```

**Arguments**

A	adjacency matrix. Can be standard R matrix or dsCMatrix (or other type in package Matrix)
method	splitting method. "SS" (default) for sign splitting, "SC" for spectral clustering
stopping	stopping rule. "NB" (default) for non-backtracking matrix spectrum, "ECV" for edge cross-validation, "Fix" for fixed D layers of partitioning (needs D value)
reg	logic value on whether regularization is needed. By default it is FALSE. Set it to be TRUE will add regularization, which help the performance on sparse networks, but it will make the computation slower.
n.min	integer number. The algorithm will stop splitting if the current size is $\leq 2 * n.min$ .
D	the number of layers to partition, if stopping=="Fix".
notree	logical value on whether the tree and the corresponding similarity will be computed. If TRUE (default), will not produce the data.tree object or the community similarity matrix. Only the cluster label and the tree path strings will be returned. This typically makes the runing faster.

**Details**

For stopping rules, ECV is nonparametric rank evaluation by cross-validation, a more generally applicable approach without assuming SBM or its variants. ECV is also applicable for weighted networks. So it is believed to be more robust than NB but less effective if the true model is close to BTSBM. However, the ECV is computationally much more intensive.

Notice that the algorithm does not rely on the assumption of the BTSBM. But the estimated probability matrix from the output is based on the BTSBM.

**Value**

A list of the following objects:

labels	detected community labels of nodes
nc1	number of clusters from the algorithm

`cluster.tree` a data.tree object for the binary tree between communities  
`P` estimated connection probability matrix between n nodes, according to BTSBM  
`node.bin.sim.mat` binary string similarity between nodes  
`comm.bin.sim.mat` binary string similarity between communities  
`tree.path` a list of strings to describe the path from root to each community along the tree

### Author(s)

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### References

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### Examples

```

dt <- BTSBM(n=1600,d=4,a.seq=0.2^seq(0,4),lambda=50)
A <- dt$A.list[[1]]
# you can try various versions of the algorithm as below: the Fix is fastest and ECV is slowest.
system.time(HCD.result <- HCD(A,method="SC",stopping="Fix",D=4))
  
```

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HCDplot

*plot the result of hierarchical community detection*

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### Description

Generate dendrogram of the HCD result.

### Usage

```
HCDplot(hcd,mode="community",labels=NULL,main=NULL,label.cex=1)
```

### Arguments

`hcd` The result of an HCD call.  
`mode` plotting community hierarchy or node hierarchy. The default value is "community", indicating plotting hierarchy between communities. Alternatively, the plot is for all nodes, which is not recommended because usually there are too many of them.

labels	the labels of the each leaf of the tree. By default, the community/node index is used. The user can also specify another sequence of characters.
main	title of the plot.
label.cex	size of the leaf label in the plot. When plotting node hierarchy, typically there are too many nodes so the labels will seriously overlap. Use a smaller size (say, label.cex=0.3) may help.

**Value**

No return value, called for visualization.

**Author(s)**

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**References**

Li, T., Lei, L., Bhattacharyya, S., Van den Berge, K., Sarkar, P., Bickel, P.J. and Levina, E., 2022. Hierarchical community detection by recursive partitioning. *Journal of the American Statistical Association*, 117(538), pp.951-968.

**Examples**

```
dt <- BTSBM(n=80,d=4,a.seq=0.2^seq(0,4),lambda=20)
A <- dt$A.list[[1]]
system.time(HCD.result <- HCD(A,method="SC",stopping="Fix",D=4,notree=FALSE,n.min=5))

HCDplot(HCD.result,mode="community",main="Community Tree")
```

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