

Package ‘ddpca’

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Title Diagonally Dominant Principal Component Analysis

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Description Efficient procedures for fitting the DD-PCA (Ke et al., 2019, <[doi:10.48550/arXiv.1906.00051](https://doi.org/10.48550/arXiv.1906.00051)>) by decomposing a large covariance matrix into a low-rank matrix plus a diagonally dominant matrix. The implementation of DD-PCA includes the convex approach using the Alternating Direction Method of Multipliers (ADMM) and the non-convex approach using the iterative projection algorithm. Applications of DD-PCA to large covariance matrix estimation and global multiple testing are also included in this package.

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ddpca-package

*Diagonally Dominant Principal Component Analysis***Description**

Efficient procedures for fitting the DD-PCA (Ke et al., 2019, <arXiv:1906.00051>) by decomposing a large covariance matrix into a low-rank matrix plus a diagonally dominant matrix. The implementation of DD-PCA includes the convex approach using the Alternating Direction Method of Multipliers (ADMM) and the non-convex approach using the iterative projection algorithm. Applications of DD-PCA to large covariance matrix estimation and global multiple testing are also included in this package.

Details

The DESCRIPTION file:

Index of help topics:

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| DDHC | DD-HC test |
| DDPCA_convex | Diagonally Dominant Principal Component Analysis using Convex approach |
| DDPCA_nonconvex | Diagonally Dominant Principal Component Analysis using Nonconvex approach |
| HCdetection | Higher Criticism for detecting rare and weak signals |
| IHCDD | IHC-DD test |
| ProjDD | Projection onto the Diagonally Dominant Cone |
| ProjSDD | Projection onto the Symmetric Diagonally Dominant Cone |
| ddpca-package | Diagonally Dominant Principal Component Analysis |

This package contains [DDPCA_nonconvex](#) and [DDPCA_convex](#) function, which decomposes a positive semidefinite matrix into a low rank component, and a diagonally dominant component using either nonconvex approach or convex approach.

Note

Please cite the reference paper to cite this R package.

Author(s)

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References

Ke, Z., Xue, L. and Yang, F., 2019. Diagonally Dominant Principal Component Analysis. Journal of Computational and Graphic Statistics, under review.

DDHC

*DD-HC test***Description**

Combining DDPCA with orthodox Higher Criticism for detecting sparse mean effect.

Usage

```
DDHC(X, known_Sigma = NA, method = "nonconvex", K = 1, lambda = 3,
max_iter_nonconvex = 15, SDD_approx = TRUE, max_iter_SDD = 20, eps = NA,
rho = 20, max_iter_convex = 50, alpha = 0.5, pvalcut = NA)
```

Arguments

| | |
|--------------------|--|
| X | A $n \times p$ data matrix, where each row is drawn i.i.d from $\mathcal{N}(\mu, \Sigma)$ |
| known_Sigma | The true covariance matrix of data. Default NA. If NA, then Σ will be estimated from data matrix X. |
| method | Either "convex" or "nonconvex", indicating which method to use for DDPCA. |
| K | Argument in function DDPCA_nonconvex. Need to be specified when method = "nonconvex" |
| lambda | Argument in function DDPCA_convex. Need to be specified when method = "convex" |
| max_iter_nonconvex | Argument in function DDPCA_nonconvex. |
| SDD_approx | Argument in function DDPCA_nonconvex. |
| max_iter_SDD | Argument in function DDPCA_nonconvex. |
| eps | Argument in function DDPCA_nonconvex. |
| rho | Argument in function DDPCA_convex. |
| max_iter_convex | Argument in function DDPCA_convex. |
| alpha | Argument in function HCdetection. |
| pvalcut | Argument in function HCdetection. |

Details

See reference paper for more details.

Value

Returns a list containing the following items

| | |
|-----|--|
| H | 0 or 1 scalar indicating whether H_0 the global null is rejected (1) or not rejected (0). The use of H is not recommended as it's approximately valid only when p is sufficiently large and mean effect in alternative is really sparse. |
| HCT | DD-HC Test statistic |

Author(s)

Fan Yang <fyang1@uchicago.edu>

References

Ke, Z., Xue, L. and Yang, F., 2019. Diagonally Dominant Principal Component Analysis. Journal of Computational and Graphic Statistics, under review.

See Also

[IHCDD](#), [HCdetection](#), [DDPCA_convex](#), [DDPCA_nonconvex](#)

Examples

```
library(MASS)
n = 200
p = 200
k = 3
rho = 0.5
a = 0:(p-1)
Sigma_mu = rho^abs(outer(a,a, '-'))
Sigma_mu = (diag(p) + Sigma_mu)/2 # Now Sigma_mu is a symmetric diagonally dominant matrix
B = matrix(rnorm(p*k),nrow = p)
Sigma = Sigma_mu + B %*% t(B)
X = mvrnorm(n,rep(0,p),Sigma)
results = DDHC(X,K = k)
print(results$H)
print(results$HCT)
```

DDPCA_convex

Diagonally Dominant Principal Component Analysis using Convex approach

Description

This function decomposes a positive semidefinite matrix into a low rank component, and a diagonally dominant component by solving a convex relaxation using ADMM.

Usage

```
DDPCA_convex(Sigma, lambda, rho = 20, max_iter_convex = 50)
```

Arguments

| | |
|-----------------|--|
| Sigma | Input matrix of size $n \times n$ |
| lambda | The parameter in the convex program that controls the rank of the low rank component |
| rho | The parameter used in each ADMM update. |
| max_iter_convex | Maximal number of iterations of ADMM update. |

Details

This function decomposes a positive semidefinite matrix Σ into a low rank component L and a symmetric diagonally dominant component A , by solving the following convex program

$$\begin{aligned} & \text{minimize} && 0.5 * \|\Sigma - L - A\|^2 + \lambda \|L\|_* \\ & \text{subject to} && A \in SDD \end{aligned}$$

where $\|L\|_*$ is the nuclear norm of L (sum of singular values) and SDD is the symmetric diagonally dominant cone.

Value

A list containing the following items

| | |
|---|-----------------------------------|
| L | The low rank component |
| A | The diagonally dominant component |

Author(s)

Fan Yang <fyang1@uchicago.edu>

References

Ke, Z., Xue, L. and Yang, F., 2019. Diagonally Dominant Principal Component Analysis. Journal of Computational and Graphic Statistics, under review.

See Also

[DDPCA_nonconvex](#)

Examples

```
library(MASS)
p = 30
n = 30
k = 3
rho = 0.5
a = 0:(p-1)
Sigma_mu = rho^abs(outer(a,a, '-'))
Sigma_mu = (diag(p) + Sigma_mu)/2 # Now Sigma_mu is a symmetric diagonally dominant matrix
mu = mvrnorm(n,rep(0,p),Sigma_mu)
B = matrix(rnorm(p*k),nrow = p)
F = matrix(rnorm(k*n),nrow = k)
Y = mu + t(B %*% F)
Sigma_sample = cov(Y)
result = DDPCA_convex(Sigma_sample,lambda=3)
```

| | |
|-----------------|--|
| DDPCA_nonconvex | <i>Diagonally Dominant Principal Component Analysis using Nonconvex approach</i> |
|-----------------|--|

Description

This function decomposes a positive semidefinite matrix into a low rank component, and a diagonally dominant component using an iterative projection algorithm.

Usage

```
DDPCA_nonconvex(Sigma, K, max_iter_nonconvex = 15, SDD_approx = TRUE,
max_iter_SDD = 20, eps = NA)
```

Arguments

| | |
|--------------------|--|
| Sigma | Input matrix of size $n \times n$ |
| K | A positive integer indicating the rank of the low rank component. |
| max_iter_nonconvex | Maximal number of iterations of the iterative projection algorithm. |
| SDD_approx | If set to TRUE, then the projection onto SDD cone step in each iteration will be replaced by projection onto DD cone followed by symmetrization. This approximation will reduce the computational cost, but the output matrix A may only be approximately diagonally dominant. |
| max_iter_SDD, eps | Arguments in function ProjSDD. Matters only when SDD_approx = False. |

Details

This function performs iterative projection algorithm to decompose a positive semidefinite matrix Sigma into a low rank component L and a symmetric diagonally dominant component A. The projection onto the set of low rank matrices is done via eigenvalue decomposition, while the projection onto the symmetric diagonally dominant (SDD) cone is done via function ProjSDD, unless SDD_approx = TRUE where an approximation is used to speed up the algorithm.

Value

A list containing the following items

| | |
|---|-----------------------------------|
| L | The low rank component |
| A | The diagonally dominant component |

Author(s)

Fan Yang <fyang1@uchicago.edu>

References

Ke, Z., Xue, L. and Yang, F., 2019. Diagonally Dominant Principal Component Analysis. Journal of Computational and Graphic Statistics, under review.

See Also

[DDPCA_convex](#)

Examples

```
library(MASS)
p = 200
n = 200
k = 3
rho = 0.5
a = 0:(p-1)
Sigma_mu = rho^abs(outer(a,a, '-'))
Sigma_mu = (diag(p) + Sigma_mu)/2 # Now Sigma_mu is a symmetric diagonally dominant matrix
mu = mvrnorm(n,rep(0,p),Sigma_mu)
B = matrix(rnorm(p*k),nrow = p)
F = matrix(rnorm(k*n),nrow = k)
Y = mu + t(B %*% F)
Sigma_sample = cov(Y)
result = DDPCA_nonconvex(Sigma_sample,K=k)
```

HCdetection

Higher Criticism for detecting rare and weak signals

Description

This function takes a bunch of p-values as input and output the Higher Criticism statistics as well as the decision (rejection or not).

Usage

```
HCdetection(p, alpha = 0.5, pvalcut = NA)
```

Arguments

| | |
|---------|--|
| p | A vector of size n containing p-values from data |
| alpha | A number between 0 and 1. The smallest $\alpha \cdot n$ p-values will be used to calculate the HC statistic. Default is 0.5. |
| pvalcut | A number between 0 and 1. Those small p-values (smaller than pvalcut) will be taken away to avoid heavy tails of test statistic. Set it to NA is equivalent to setting it to $1/n$. |

Details

This function is an adaptation of the Matlab code here <http://www.stat.cmu.edu/~jiashun/Research/software/HC/>

Value

Returns a list containing the following items

| | |
|-----|--|
| H | 0 or 1 scalar indicating whether H_0 the global null is rejected (1) or not rejected (0) |
| HCT | Higher Criticism test statistic |

Author(s)

Fan Yang <fyang1@uchicago.edu>

References

Donoho, D. and Jin, J., Higher criticism for detecting sparse heterogeneous mixtures. *Ann. Statist.* 32 (2004), no. 3, 962–994.

Ke, Z., Xue, L. and Yang, F., 2019. Diagonally Dominant Principal Component Analysis. *Journal of Computational and Graphic Statistics*, under review.

Examples

```
n = 1e5
data = rnorm(n)
p = 2*(1 - pnorm(abs(data)))
result = HCdetection(p)
print(result$H)
print(result$HCT)
```

IHCDD

IHC-DD test

Description

Combining Innovated Higher Criticism with DDPCA for detecting sparse mean effect.

Usage

```
IHCDD(X, method = "nonconvex", K = 1, lambda = 3, max_iter_nonconvex = 15,
SDD_approx = TRUE, max_iter_SDD = 20, eps = NA, rho = 20, max_iter_convex = 50,
alpha = 0.5, pvalcut = NA)
```


Arguments

| | |
|---------------------------------|---|
| <code>X</code> | A $n \times p$ data matrix, where each row is drawn i.i.d from $\mathcal{N}(\mu, \Sigma)$ |
| <code>method</code> | Either "convex" or "nonconvex", indicating which method to use for DDPCA. |
| <code>K</code> | Argument in function <code>DDPCA_nonconvex</code> . Need to be specified when <code>method = "nonconvex"</code> |
| <code>lambda</code> | Argument in function <code>DDPCA_convex</code> . Need to be specified when <code>method = "convex"</code> |
| <code>max_iter_nonconvex</code> | Argument in function <code>DDPCA_nonconvex</code> . |
| <code>SDD_approx</code> | Argument in function <code>DDPCA_nonconvex</code> . |
| <code>max_iter_SDD</code> | Argument in function <code>DDPCA_nonconvex</code> . |
| <code>eps</code> | Argument in function <code>DDPCA_nonconvex</code> . |
| <code>rho</code> | Argument in function <code>DDPCA_convex</code> . |
| <code>max_iter_convex</code> | Argument in function <code>DDPCA_convex</code> . |
| <code>alpha</code> | Argument in function <code>HCdetection</code> . |
| <code>pvalcut</code> | Argument in function <code>HCdetection</code> . |

Details

See reference paper for more details.

Value

Returns a list containing the following items

| | |
|------------------|--|
| <code>H</code> | 0 or 1 scalar indicating whether H_0 the global null is rejected (1) or not rejected (0). Not recommended for use. |
| <code>HCT</code> | IHC-DD Test statistic |

Author(s)

Fan Yang <fyang1@uchicago.edu>

References

Ke, Z., Xue, L. and Yang, F., 2019. Diagonally Dominant Principal Component Analysis. *Journal of Computational and Graphic Statistics*, under review.

See Also

[DDHC](#), [HCdetection](#), [DDPCA_convex](#), [DDPCA_nonconvex](#)

Examples

```

library(MASS)
n = 200
p = 200
k = 3
rho = 0.5
a = 0:(p-1)
Sigma_mu = rho^abs(outer(a,a,'-'))
Sigma_mu = (diag(p) + Sigma_mu)/2 # Now Sigma_mu is a symmetric diagonally dominant matrix
B = matrix(rnorm(p*k),nrow = p)
Sigma = Sigma_mu + B %*% t(B)
X = mvrnorm(n,rep(0,p),Sigma)
results = IHCCD(X,K = k)
print(results$H)
print(results$HCT)

```

ProjDD

Projection onto the Diagonally Dominant Cone

Description

Given a matrix C , this function outputs the projection of C onto the cones of diagonally dominant matrices.

Usage

```
ProjDD(C)
```

Arguments

C $A\ n \times n$ matrix

Details

This function projects the input matrix C of size $n \times n$ onto the cones of diagonally dominant matrices defined as

$$\{A = (a_{ij})_{1 \leq i \leq n, 1 \leq j \leq n} : a_{jj} \geq \sum_{k \neq j} |a_{jk}| \text{ for all } 1 \leq j \leq n\}$$

The algorithm is described in Mendoza, M., Raydan, M. and Tarazaga, P., 1998. Computing the nearest diagonally dominant matrix.

Value

$A\ n \times n$ diagonally dominant matrix

Author(s)

Fan Yang <fyang1@uchicago.edu>

References

- Mendoza, M., Raydan, M. and Tarazaga, P., 1998. Computing the nearest diagonally dominant matrix. Numerical linear algebra with applications, 5(6), pp.461-474.
- Ke, Z., Xue, L. and Yang, F., 2019. Diagonally Dominant Principal Component Analysis. Journal of Computational and Graphic Statistics, under review.

See Also

[ProjSDD](#)

Examples

```
ProjDD(matrix(runif(100),nrow=10))
```

ProjSDD

Projection onto the Symmetric Diagonally Dominant Cone

Description

Given a matrix C , this function outputs the projection of C onto the cones of symmetric diagonally dominant matrices using Dykstra's projection algorithm.

Usage

```
ProjSDD(A, max_iter_SDD = 20, eps = NA)
```

Arguments

| | |
|---------------------------|--|
| <code>A</code> | Input matrix of size $n \times n$ |
| <code>max_iter_SDD</code> | Maximal number of iterations of the Dykstra's projection algorithm |
| <code>eps</code> | The iterations will stop either when the Frobenious norm of difference matrix between two updates is less than <code>eps</code> or after <code>max_iter_SDD</code> steps. If set to <code>NA</code> , then no check will be done during iterations and the iteration will stop after <code>max_iter_SDD</code> steps. Default is <code>NA</code> . |

Details

This function projects the input matrix C of size $n \times n$ onto the cones of symmetric diagonally dominant matrices defined as

$$\{A = (a_{ij})_{1 \leq i \leq n, 1 \leq j \leq n} : a_{ij} = a_{ji}, a_{jj} \geq \sum_{k \neq j} |a_{jk}| \text{ for all } 1 \leq j \leq n, 1 \leq i \leq n\}$$

It makes use of Dykstra's algorithm, which is a variation of iterative projection algorithm. The two key steps are projection onto the diagonally dominant cone by calling function ProjDD and projection onto the symmetric matrix cone by simple symmetrization.

More details can be found in Mendoza, M., Raydan, M. and Tarazaga, P., 1998. Computing the nearest diagonally dominant matrix.

Value

A $n \times n$ symmetric diagonally dominant matrix

Author(s)

Fan Yang <fyang1@uchicago.edu>

References

Mendoza, M., Raydan, M. and Tarazaga, P., 1998. Computing the nearest diagonally dominant matrix. Numerical linear algebra with applications, 5(6), pp.461-474.

Ke, Z., Xue, L. and Yang, F., 2019. Diagonally Dominant Principal Component Analysis. Journal of Computational and Graphic Statistics, under review.

See Also

[ProjDD](#)

Examples

```
ProjSDD(matrix(runif(100),nrow=10))
```

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