Package ‘PEtests’

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Title Power-Enhanced (PE) Tests for High-Dimensional Data

Version 0.1.0

Description
Two-sample power-enhanced mean tests, covariance tests, and simultaneous tests on mean vectors and covariance matrices for high-dimensional data. Methods of these PE tests are presented in Yu, Li, and Xue (2022) <doi:10.1080/01621459.2022.2126781>;
Yu, Li, Xue, and Li (2022) <doi:10.1080/01621459.2022.2061354>.

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Contents

`PEtests-package` *Power-Enhanced (PE) Tests for High-Dimensional Data*

Description

The package implements several two-sample power-enhanced mean tests, covariance tests, and simultaneous tests on mean vectors and covariance matrices for high-dimensional data.

Details

There are three main functions:
`covtest`
`meantest`
`simultest`

References

Chen, S. X. and Qin, Y. L. (2010). A two-sample test for high-dimensional data with applications to gene-set testing. *Annals of Statistics*, 38(2):808–835. doi:10.1214/09AOS716

Cai, T. T., Liu, W., and Xia, Y. (2013). Two-sample covariance matrix testing and support recovery in high-dimensional and sparse settings. *Journal of the American Statistical Association*, 108(501):265–277. doi:10.1080/01621459.2012.758041

Cai, T. T., Liu, W., and Xia, Y. (2014). Two-sample test of high dimensional means under dependence. *Journal of the Royal Statistical Society: Series B: Statistical Methodology*, 76(2):349–372. doi:10.1111/rssb.12034

Li, J. and Chen, S. X. (2012). Two sample tests for high-dimensional covariance matrices. *The Annals of Statistics*, 40(2):908–940. doi:10.1214/12AOS993

Yu, X., Li, D., and Xue, L. (2022). Fisher's combined probability test for high-dimensional covariance matrices. *Journal of the American Statistical Association*, (in press):1–14. doi:10.1080/01621459.2022.2126781

Yu, X., Li, D., Xue, L., and Li, R. (2022). Power-enhanced simultaneous test of high-dimensional mean vectors and covariance matrices with application to gene-set testing. *Journal of the American Statistical Association*, (in press):1–14. doi:10.1080/01621459.2022.2061354

Examples

```
n1 = 100; n2 = 100; pp = 500
set.seed(1)
X = matrix(rnorm(n1*pp), nrow=n1, ncol=pp)
Y = matrix(rnorm(n2*pp), nrow=n2, ncol=pp)
covtest(X, Y)
meantest(X, Y)
simultest(X, Y)
```

---

covtest — *Two-sample covariance tests for high-dimensional data*

Description

This function implements five two-sample covariance tests on high-dimensional covariance matrices. Let $\mathbf{X} \in \mathbb{R}^p$ and $\mathbf{Y} \in \mathbb{R}^p$ be two p-dimensional populations with mean vectors $(\boldsymbol{\mu}_1, \boldsymbol{\mu}_2)$ and covariance matrices $(\boldsymbol{\Sigma}_1, \boldsymbol{\Sigma}_2)$, respectively. The problem of interest is to test the equality of the two covariance matrices:

$$H_{0c} : \boldsymbol{\Sigma}_1 = \boldsymbol{\Sigma}_2.$$

Suppose $\{\mathbf{X}_1, \ldots, \mathbf{X}_{n_1}\}$ are i.i.d. copies of $\mathbf{X}$, and $\{\mathbf{Y}_1, \ldots, \mathbf{Y}_{n_2}\}$ are i.i.d. copies of $\mathbf{Y}$. We denote `dataX=`$(\mathbf{X}_1, \ldots, \mathbf{X}_{n_1})^\top \in \mathbb{R}^{n_1 \times p}$ and `dataY=`$(\mathbf{Y}_1, \ldots, \mathbf{Y}_{n_2})^\top \in \mathbb{R}^{n_2 \times p}$.

Usage

```
covtest(dataX,dataY,method='pe.comp',delta=NULL)
```

Arguments

`dataX`	an n_1 by p data matrix
`dataY`	an n_2 by p data matrix
`method`	the method type (default = `'pe.comp'`); chosen from

- `'clx'`: the l_∞-norm-based covariance test, proposed in Cai et al. (2013); see `covtest.clx` for details.
- `'lc'`: the l_2-norm-based covariance test, proposed in Li and Chen (2012); see `covtest.lc` for details.
- `'pe.cauchy'`: the PE covariance test via Cauchy combination; see `covtest.pe.cauchy` for details.
- `'pe.comp'`: the PE covariance test via the construction of PE components; see `covtest.pe.comp` for details.

- `'pe.fisher'`: the PE covariance test via Fisher's combination; see `covtest.pe.fisher` for details.

`delta` This is needed only in `method='pe.comp'`; see `covtest.pe.comp` for details. The default is NULL.

Value

`method` the method type

`stat` the value of test statistic

`pval` the p-value for the test.

References

Cai, T. T., Liu, W., and Xia, Y. (2013). Two-sample covariance matrix testing and support recovery in high-dimensional and sparse settings. *Journal of the American Statistical Association*, 108(501):265–277.

Li, J. and Chen, S. X. (2012). Two sample tests for high-dimensional covariance matrices. *The Annals of Statistics*, 40(2):908–940.

Yu, X., Li, D., and Xue, L. (2022). Fisher's combined probability test for high-dimensional covariance matrices. *Journal of the American Statistical Association*, (in press):1–14.

Yu, X., Li, D., Xue, L., and Li, R. (2022). Power-enhanced simultaneous test of high-dimensional mean vectors and covariance matrices with application to gene-set testing. *Journal of the American Statistical Association*, (in press):1–14.

Examples

```
n1 = 100; n2 = 100; pp = 500
set.seed(1)
X = matrix(rnorm(n1*pp), nrow=n1, ncol=pp)
Y = matrix(rnorm(n2*pp), nrow=n2, ncol=pp)
covtest(X,Y)
```

---

covtest.clx *Two-sample high-dimensional covariance test (Cai, Liu and Xia, 2013)*

Description

This function implements the two-sample l_∞-norm-based high-dimensional covariance test proposed in Cai, Liu and Xia (2013). Suppose $\{\mathbf{X}_1, \ldots, \mathbf{X}_{n_1}\}$ are i.i.d. copies of $\mathbf{X}$, and $\{\mathbf{Y}_1, \ldots, \mathbf{Y}_{n_2}\}$ are i.i.d. copies of $\mathbf{Y}$. The test statistic is defined as

$$T_{CLX} = \max_{1\le i,j\le p} \frac{(\hat{\sigma}_{ij1} - \hat{\sigma}_{ij2})^2}{\hat{\theta}_{ij1}/n_1 + \hat{\theta}_{ij2}/n_2},$$

where $\hat{\sigma}_{ij1}$ and $\hat{\sigma}_{ij2}$ are the sample covariances, and $\hat{\theta}_{ij1}/n_1 + \hat{\theta}_{ij2}/n_2$ estimates the variance of $\hat{\sigma}_{ij1} - \hat{\sigma}_{ij2}$. The explicit formulas of $\hat{\sigma}_{ij1}$, $\hat{\sigma}_{ij2}$, $\hat{\theta}_{ij1}$ and $\hat{\theta}_{ij2}$ can be found in Section 2 of Cai, Liu and Xia (2013). With some regularity conditions, under the null hypothesis $H_{0c}: \mathbf{\Sigma}_1 = \mathbf{\Sigma}_2$, the test statistic $T_{CLX} - 4\log p + \log\log p$ converges in distribution to a Gumbel distribution $G_{cov}(x) = \exp(-\frac{1}{\sqrt{8\pi}}\exp(-\frac{x}{2}))$ as $n_1, n_2, p \to \infty$. The asymptotic p-value is obtained by

$$p_{CLX} = 1 - G_{cov}(T_{CLX} - 4\log p + \log\log p).$$

Usage

```
covtest.clx(dataX,dataY)
```

Arguments

`dataX`	an n_1 by p data matrix
`dataY`	an n_2 by p data matrix

Value

`stat` the value of test statistic

`pval` the p-value for the test.

References

Cai, T. T., Liu, W., and Xia, Y. (2013). Two-sample covariance matrix testing and support recovery in high-dimensional and sparse settings. *Journal of the American Statistical Association*, 108(501):265–277.

Examples

```
n1 = 100; n2 = 100; pp = 500
set.seed(1)
X = matrix(rnorm(n1*pp), nrow=n1, ncol=pp)
Y = matrix(rnorm(n2*pp), nrow=n2, ncol=pp)
covtest.clx(X,Y)
```

`covtest.lc` *Two-sample high-dimensional covariance test (Li and Chen, 2012)*

Description

This function implements the two-sample l_2-norm-based high-dimensional covariance test proposed by Li and Chen (2012). Suppose $\{\mathbf{X}_1, \ldots, \mathbf{X}_{n_1}\}$ are i.i.d. copies of $\mathbf{X}$, and $\{\mathbf{Y}_1, \ldots, \mathbf{Y}_{n_2}\}$ are i.i.d. copies of $\mathbf{Y}$. The test statistic T_{LC} is defined as

$$T_{LC} = A_{n_1} + B_{n_2} - 2C_{n_1,n_2},$$

where A_{n_1}, B_{n_2}, and C_{n_1,n_2} are unbiased estimators for $\mathrm{tr}(\mathbf{\Sigma}_1^2)$, $\mathrm{tr}(\mathbf{\Sigma}_2^2)$, and $\mathrm{tr}(\mathbf{\Sigma}_1\mathbf{\Sigma}_2)$, respectively. Under the null hypothesis $H_{0c}: \mathbf{\Sigma}_1 = \mathbf{\Sigma}_2$, the leading variance of T_{LC} is $\sigma^2_{T_{LC}} = 4(\frac{1}{n_1} + \frac{1}{n_2})^2\mathrm{tr}^2(\mathbf{\Sigma}^2)$, which can be consistently estimated by $\hat{\sigma}^2_{LC}$. The explicit formulas of A_{n_1},

B_{n_2}, C_{n_1,n_2} and $\hat{\sigma}^2_{T_{LC}}$ can be found in Equations (2.1), (2.2) and Theorem 1 of Li and Chen (2012). With some regularity conditions, under the null hypothesis $H_{0c} : \mathbf{\Sigma}_1 = \mathbf{\Sigma}_2$, the test statistic T_{LC} converges in distribution to a standard normal distribution as $n_1, n_2, p \to \infty$. The asymptotic p-value is obtained by

$$p_{LC} = 1 - \Phi(T_{LC}/\hat{\sigma}_{T_{LC}}),$$

where $\Phi(\cdot)$ is the cdf of the standard normal distribution.

Usage

```
covtest.lc(dataX,dataY)
```

Arguments

`dataX`	an n_1 by p data matrix
`dataY`	an n_2 by p data matrix

Value

`stat` the value of test statistic

`pval` the p-value for the test.

References

Li, J. and Chen, S. X. (2012). Two sample tests for high-dimensional covariance matrices. *The Annals of Statistics*, 40(2):908–940.

Examples

```
n1 = 100; n2 = 100; pp = 500
set.seed(1)
X = matrix(rnorm(n1*pp), nrow=n1, ncol=pp)
Y = matrix(rnorm(n2*pp), nrow=n2, ncol=pp)
covtest.lc(X,Y)
```

`covtest.pe.cauchy` *Two-sample PE covariance test for high-dimensional data via Cauchy combination*

Description

This function implements the two-sample PE covariance test via Cauchy combination. Suppose $\{\mathbf{X}_1, \ldots, \mathbf{X}_{n_1}\}$ are i.i.d. copies of $\mathbf{X}$, and $\{\mathbf{Y}_1, \ldots, \mathbf{Y}_{n_2}\}$ are i.i.d. copies of $\mathbf{Y}$. Let p_{LC} and p_{CLX} denote the p-values associated with the l_2-norm-based covariance test (see `covtest.lc` for details) and the l_∞-norm-based covariance test (see `covtest.clx` for details), respectively. The PE covariance test via Cauchy combination is defined as

$$T_{Cauchy} = \frac{1}{2}\tan((0.5 - p_{LC})\pi) + \frac{1}{2}\tan((0.5 - p_{CLX})\pi).$$

It has been proved that with some regularity conditions, under the null hypothesis $H_{0c} : \mathbf{\Sigma}_1 = \mathbf{\Sigma}_2$, the two tests are asymptotically independent as $n_1, n_2, p \to \infty$, and therefore T_{Cauchy} asymptotically converges in distribution to a standard Cauchy distribution. The asymptotic p-value is obtained by

$$p\text{-value} = 1 - F_{Cauchy}(T_{Cauchy}),$$

where $F_{Cauchy}(\cdot)$ is the cdf of the standard Cauchy distribution.

Usage

```
covtest.pe.cauchy(dataX,dataY)
```

Arguments

`dataX`	an n_1 by p data matrix
`dataY`	an n_2 by p data matrix

Value

`stat` the value of test statistic

`pval` the p-value for the test.

References

Yu, X., Li, D., and Xue, L. (2022). Fisher's combined probability test for high-dimensional covariance matrices. *Journal of the American Statistical Association*, (in press):1–14.

Examples

```
n1 = 100; n2 = 100; pp = 500
set.seed(1)
X = matrix(rnorm(n1*pp), nrow=n1, ncol=pp)
Y = matrix(rnorm(n2*pp), nrow=n2, ncol=pp)
covtest.pe.cauchy(X,Y)
```

`covtest.pe.comp` *Two-sample PE covariance test for high-dimensional data via PE component*

Description

This function implements the two-sample PE covariance test via the construction of the PE component. Let $T_{LC}/\hat{\sigma}_{T_{LC}}$ denote the l_2-norm-based covariance test statistic (see `covtest.lc` for details). The PE component is constructed by

$$J_c = \sqrt{p} \sum_{i=1}^{p} \sum_{j=1}^{p} T_{ij} \widehat{\xi}_{ij}^{-1/2} \mathcal{I}\{\sqrt{2} T_{ij} \widehat{\xi}_{ij}^{-1/2} + 1 > \delta_{cov}\},$$

where δ_{cov} is a threshold for the screening procedure, recommended to take the value of $\delta_{cov} = 4\log(\log(n_1+n_2))\log p$. The explicit forms of T_{ij} and $\widehat{\xi}_{ij}$ can be found in Section 3.2 of Yu et al. (2022). The PE covariance test statistic is defined as

$$T_{PE} = T_{LC}/\hat{\sigma}_{T_{LC}} + J_c.$$

With some regularity conditions, under the null hypothesis $H_{0c} : \mathbf{\Sigma}_1 = \mathbf{\Sigma}_2$, the test statistic T_{PE} converges in distribution to a standard normal distribution as $n_1, n_2, p \to \infty$. The asymptotic p-value is obtained by

$$p\text{-value} = 1 - \Phi(T_{PE}),$$

where $\Phi(\cdot)$ is the cdf of the standard normal distribution.

Usage

```
covtest.pe.comp(dataX,dataY,delta=NULL)
```

Arguments

`dataX`	an n_1 by p data matrix
`dataY`	an n_2 by p data matrix
`delta`	a scalar; the thresholding value used in the construction of the PE component. If not specified, the function uses a default value $\delta_{cov} = 4\log(\log(n_1+n_2))\log p$.

Value

`stat` the value of test statistic

`pval` the p-value for the test.

References

Yu, X., Li, D., Xue, L., and Li, R. (2022). Power-enhanced simultaneous test of high-dimensional mean vectors and covariance matrices with application to gene-set testing. *Journal of the American Statistical Association*, (in press):1–14.

Examples

```
n1 = 100; n2 = 100; pp = 500
set.seed(1)
X = matrix(rnorm(n1*pp), nrow=n1, ncol=pp)
Y = matrix(rnorm(n2*pp), nrow=n2, ncol=pp)
covtest.pe.comp(X,Y)
```

`covtest.pe.fisher` *Two-sample PE covariance test for high-dimensional data via Fisher's combination*

Description

This function implements the two-sample PE covariance test via Fisher's combination. Suppose $\{\mathbf{X}_1, \ldots, \mathbf{X}_{n_1}\}$ are i.i.d. copies of $\mathbf{X}$, and $\{\mathbf{Y}_1, \ldots, \mathbf{Y}_{n_2}\}$ are i.i.d. copies of $\mathbf{Y}$. Let p_{LC} and p_{CLX} denote the p-values associated with the l_2-norm-based covariance test (see `covtest.lc` for details) and the l_∞-norm-based covariance test (see `covtest.clx` for details), respectively. The PE covariance test via Fisher's combination is defined as

$$T_{Fisher} = -2\log(p_{LC}) - 2\log(p_{CLX}).$$

It has been proved that with some regularity conditions, under the null hypothesis $H_{0c} : \mathbf{\Sigma}_1 = \mathbf{\Sigma}_2$, the two tests are asymptotically independent as $n_1, n_2, p \to \infty$, and therefore T_{Fisher} asymptotically converges in distribution to a χ_4^2 distribution. The asymptotic p-value is obtained by

$$p\text{-value} = 1 - F_{\chi_4^2}(T_{Fisher}),$$

where $F_{\chi_4^2}(\cdot)$ is the cdf of the χ_4^2 distribution.

Usage

```
covtest.pe.fisher(dataX,dataY)
```

Arguments

`dataX`	an n_1 by p data matrix
`dataY`	an n_2 by p data matrix

Value

`stat` the value of test statistic

`pval` the p-value for the test.

References

Yu, X., Li, D., and Xue, L. (2022). Fisher's combined probability test for high-dimensional covariance matrices. *Journal of the American Statistical Association*, (in press):1–14.

Examples

```
n1 = 100; n2 = 100; pp = 500
set.seed(1)
X = matrix(rnorm(n1*pp), nrow=n1, ncol=pp)
Y = matrix(rnorm(n2*pp), nrow=n2, ncol=pp)
covtest.pe.fisher(X,Y)
```

meantest *Two-sample mean tests for high-dimensional data*

Description

This function implements five two-sample mean tests on high-dimensional mean vectors. Let $\mathbf{X} \in \mathbb{R}^p$ and $\mathbf{Y} \in \mathbb{R}^p$ be two p-dimensional populations with mean vectors $(\boldsymbol{\mu}_1, \boldsymbol{\mu}_2)$ and covariance matrices $(\boldsymbol{\Sigma}_1, \boldsymbol{\Sigma}_2)$, respectively. The problem of interest is to test the equality of the two mean vectors of the two populations:

$$H_{0m} : \boldsymbol{\mu}_1 = \boldsymbol{\mu}_2.$$

Suppose $\{\mathbf{X}_1, \ldots, \mathbf{X}_{n_1}\}$ are i.i.d. copies of $\mathbf{X}$, and $\{\mathbf{Y}_1, \ldots, \mathbf{Y}_{n_2}\}$ are i.i.d. copies of $\mathbf{Y}$. We denote `dataX`=$(\mathbf{X}_1, \ldots, \mathbf{X}_{n_1})^\top \in \mathbb{R}^{n_1 \times p}$ and `dataY`=$(\mathbf{Y}_1, \ldots, \mathbf{Y}_{n_2})^\top \in \mathbb{R}^{n_2 \times p}$.

Usage

```
meantest(dataX,dataY,method='pe.comp',delta=NULL)
```

Arguments

dataX	an n_1 by p data matrix
dataY	an n_2 by p data matrix
method	the method type (default = 'pe.comp'); chosen from • 'clx': the l_∞-norm-based mean test, proposed in Cai et al. (2014); see meantest.clx for details. • 'cq': the l_2-norm-based mean test, proposed in Chen and Qin (2010); see meantest.cq for details. • 'pe.cauchy': the PE mean test via Cauchy combination; see meantest.pe.cauchy for details. • 'pe.comp': the PE mean test via the construction of PE components; see meantest.pe.comp for details. • 'pe.fisher': the PE mean test via Fisher's combination; see meantest.pe.fisher for details.
delta	This is needed only in method='pe.comp'; see meantest.pe.comp for details. The default is NULL.

Value

`method` the method type

`stat` the value of test statistic

`pval` the p-value for the test.

References

Chen, S. X. and Qin, Y. L. (2010). A two-sample test for high-dimensional data with applications to gene-set testing. *Annals of Statistics*, 38(2):808–835.

Cai, T. T., Liu, W., and Xia, Y. (2014). Two-sample test of high dimensional means under dependence. *Journal of the Royal Statistical Society: Series B: Statistical Methodology*, 76(2):349–372.

Yu, X., Li, D., Xue, L., and Li, R. (2022). Power-enhanced simultaneous test of high-dimensional mean vectors and covariance matrices with application to gene-set testing. *Journal of the American Statistical Association*, (in press):1–14.

Examples

```
n1 = 100; n2 = 100; pp = 500
set.seed(1)
X = matrix(rnorm(n1*pp), nrow=n1, ncol=pp)
Y = matrix(rnorm(n2*pp), nrow=n2, ncol=pp)
meantest(X,Y)
```

---

meantest.clx — *Two-sample high-dimensional mean test (Cai, Liu and Xia, 2014)*

Description

This function implements the two-sample l_∞-norm-based high-dimensional mean test proposed in Cai, Liu and Xia (2014). Suppose $\{\mathbf{X}_1, \ldots, \mathbf{X}_{n_1}\}$ are i.i.d. copies of $\mathbf{X}$, and $\{\mathbf{Y}_1, \ldots, \mathbf{Y}_{n_2}\}$ are i.i.d. copies of $\mathbf{Y}$. The test statistic is defined as

$$M_{CLX} = \frac{n_1 n_2}{n_1 + n_2} \max_{1 \le j \le p} \frac{(\bar{X}_j - \bar{Y}_j)^2}{\frac{1}{n_1+n_2}[\sum_{u=1}^{n_1}(X_{uj} - \bar{X}_j)^2 + \sum_{v=1}^{n_2}(Y_{vj} - \bar{Y}_j)^2]}$$

With some regularity conditions, under the null hypothesis $H_{0c} : \mathbf{\Sigma}_1 = \mathbf{\Sigma}_2$, the test statistic $M_{CLX} - 2\log p + \log\log p$ converges in distribution to a Gumbel distribution $G_{mean}(x) = \exp(-\frac{1}{\sqrt{\pi}}\exp(-\frac{x}{2}))$ as $n_1, n_2, p \to \infty$. The asymptotic p-value is obtained by

$$p_{CLX} = 1 - G_{mean}(M_{CLX} - 2\log p + \log\log p).$$

Usage

```
meantest.clx(dataX,dataY)
```

Arguments

`dataX`	an n_1 by p data matrix
`dataY`	an n_2 by p data matrix

Value

`stat` the value of test statistic

`pval` the p-value for the test.

References

Cai, T. T., Liu, W., and Xia, Y. (2014). Two-sample test of high dimensional means under dependence. *Journal of the Royal Statistical Society: Series B: Statistical Methodology*, 76(2):349–372.

Examples

```
n1 = 100; n2 = 100; pp = 500
set.seed(1)
X = matrix(rnorm(n1*pp), nrow=n1, ncol=pp)
Y = matrix(rnorm(n2*pp), nrow=n2, ncol=pp)
meantest.clx(X,Y)
```

`meantest.cq` *Two-sample high-dimensional mean test (Chen and Qin, 2010)*

Description

This function implements the two-sample l_2-norm-based high-dimensional mean test proposed by Chen and Qin (2010). Suppose $\{\mathbf{X}_1, \ldots, \mathbf{X}_{n_1}\}$ are i.i.d. copies of $\mathbf{X}$, and $\{\mathbf{Y}_1, \ldots, \mathbf{Y}_{n_2}\}$ are i.i.d. copies of $\mathbf{Y}$. The test statistic M_{CQ} is defined as

$$M_{CQ} = \frac{1}{n_1(n_1-1)} \sum_{u \neq v}^{n_1} \mathbf{X}_u' \mathbf{X}_v + \frac{1}{n_2(n_2-1)} \sum_{u \neq v}^{n_2} \mathbf{Y}_u' \mathbf{Y}_v - \frac{2}{n_1 n_2} \sum_{u}^{n_1} \sum_{v}^{n_2} \mathbf{X}_u' \mathbf{Y}_v.$$

Under the null hypothesis $H_{0m} : \boldsymbol{\mu}_1 = \boldsymbol{\mu}_2$, the leading variance of M_{CQ} is $\sigma^2_{M_{CQ}} = \frac{2}{n_1(n_1-1)} \text{tr}(\mathbf{\Sigma}_1^2) + \frac{2}{n_2(n_2-1)} \text{tr}(\mathbf{\Sigma}_2^2) + \frac{4}{n_1 n_2} \text{tr}(\mathbf{\Sigma}_1 \mathbf{\Sigma}_2)$, which can be consistently estimated by $\widehat{\sigma}^2_{M_{CQ}} = \frac{2}{n_1(n_1-1)} \widehat{\text{tr}(\mathbf{\Sigma}_1^2)} + \frac{2}{n_2(n_2-1)} \widehat{\text{tr}(\mathbf{\Sigma}_2^2)} + \frac{4}{n_1 n_2} \text{tr}(\widehat{\mathbf{\Sigma}_1 \mathbf{\Sigma}_2})$. The explicit formulas of $\widehat{\text{tr}(\mathbf{\Sigma}_1^2)}$, $\widehat{\text{tr}(\mathbf{\Sigma}_2^2)}$, and $\text{tr}(\widehat{\mathbf{\Sigma}_1 \mathbf{\Sigma}_2})$ can be found in Section 3 of Chen and Qin (2010). With some regularity conditions, under the null hypothesis $H_{0m} : \boldsymbol{\mu}_1 = \boldsymbol{\mu}_2$, the test statistic M_{CQ} converges in distribution to a standard normal distribution as $n_1, n_2, p \to \infty$. The asymptotic p-value is obtained by

$$p_{CQ} = 1 - \Phi(M_{CQ}/\hat{\sigma}_{M_{CQ}}),$$

where $\Phi(\cdot)$ is the cdf of the standard normal distribution.

Usage

```
meantest.cq(dataX,dataY)
```

Arguments

`dataX`	an n_1 by p data matrix
`dataY`	an n_2 by p data matrix

Value

`stat` the value of test statistic

`pval` the p-value for the test.

References

Chen, S. X. and Qin, Y. L. (2010). A two-sample test for high-dimensional data with applications to gene-set testing. *Annals of Statistics*, 38(2):808–835.

Examples

```
n1 = 100; n2 = 100; pp = 500
set.seed(1)
X = matrix(rnorm(n1*pp), nrow=n1, ncol=pp)
Y = matrix(rnorm(n2*pp), nrow=n2, ncol=pp)
meantest.cq(X,Y)
```

`meantest.pe.cauchy` *Two-sample PE mean test for high-dimensional data via Cauchy combination*

Description

This function implements the two-sample PE covariance test via Cauchy combination. Suppose $\{\mathbf{X}_1, \ldots, \mathbf{X}_{n_1}\}$ are i.i.d. copies of $\mathbf{X}$, and $\{\mathbf{Y}_1, \ldots, \mathbf{Y}_{n_2}\}$ are i.i.d. copies of $\mathbf{Y}$. Let p_{CQ} and p_{CLX} denote the p-values associated with the l_2-norm-based covariance test (see `meantest.cq` for details) and the l_∞-norm-based covariance test (see `meantest.clx` for details), respectively. The PE covariance test via Cauchy combination is defined as

$$M_{Cauchy} = \frac{1}{2}\tan((0.5 - p_{CQ})\pi) + \frac{1}{2}\tan((0.5 - p_{CLX})\pi).$$

It has been proved that with some regularity conditions, under the null hypothesis $H_{0m} : \boldsymbol{\mu}_1 = \boldsymbol{\mu}_2$, the two tests are asymptotically independent as $n_1, n_2, p \to \infty$, and therefore M_{Cauchy} asymptotically converges in distribution to a standard Cauchy distribution. The asymptotic p-value is obtained by

$$p\text{-value} = 1 - F_{Cauchy}(M_{Cauchy}),$$

where $F_{Cauchy}(\cdot)$ is the cdf of the standard Cauchy distribution.

Usage

```
meantest.pe.cauchy(dataX,dataY)
```

Arguments

`dataX`	an n_1 by p data matrix
`dataY`	an n_2 by p data matrix

Value

`stat` the value of test statistic

`pval` the p-value for the test.

References

Chen, S. X. and Qin, Y. L. (2010). A two-sample test for high-dimensional data with applications to gene-set testing. *Annals of Statistics*, 38(2):808–835.

Cai, T. T., Liu, W., and Xia, Y. (2014). Two-sample test of high dimensional means under dependence. *Journal of the Royal Statistical Society: Series B: Statistical Methodology*, 76(2):349–372.

Examples

```
n1 = 100; n2 = 100; pp = 500
set.seed(1)
X = matrix(rnorm(n1*pp), nrow=n1, ncol=pp)
Y = matrix(rnorm(n2*pp), nrow=n2, ncol=pp)
meantest.pe.cauchy(X,Y)
```

`meantest.pe.comp` *Two-sample PE mean test for high-dimensional data via PE component*

Description

This function implements the two-sample PE mean via the construction of the PE component. Let $M_{CQ}/\hat{\sigma}_{M_{CQ}}$ denote the l_2-norm-based mean test statistic (see `meantest.cq` for details). The PE component is constructed by

$$J_m = \sqrt{p}\sum_{i=1}^{p} M_i \widehat{\nu}_i^{-1/2} \mathcal{I}\{\sqrt{2} M_i \widehat{\nu}_i^{-1/2} + 1 > \delta_{mean}\},$$

where δ_{mean} is a threshold for the screening procedure, recommended to take the value of $\delta_{mean} = 2\log(\log(n_1 + n_2))\log p$. The explicit forms of M_i and $\widehat{\nu}_j$ can be found in Section 3.1 of Yu et al. (2022). The PE covariance test statistic is defined as

$$M_{PE} = M_{CQ}/\hat{\sigma}_{M_{CQ}} + J_m.$$

With some regularity conditions, under the null hypothesis $H_{0m} : \boldsymbol{\mu}_1 = \boldsymbol{\mu}_2$, the test statistic M_{PE} converges in distribution to a standard normal distribution as $n_1, n_2, p \to \infty$. The asymptotic p-value is obtained by

$$p\text{-value} = 1 - \Phi(M_{PE}),$$

where $\Phi(\cdot)$ is the cdf of the standard normal distribution.

Usage

```
meantest.pe.comp(dataX,dataY,delta=NULL)
```

Arguments

`dataX`	an n_1 by p data matrix
`dataY`	an n_2 by p data matrix
`delta`	a scalar; the thresholding value used in the construction of the PE component. If not specified, the function uses a default value $\delta_{mean} = 2\log(\log(n_1 + n_2))\log p$.

Value

`stat` the value of test statistic

`pval` the p-value for the test.

References

Yu, X., Li, D., Xue, L., and Li, R. (2022). Power-enhanced simultaneous test of high-dimensional mean vectors and covariance matrices with application to gene-set testing. *Journal of the American Statistical Association*, (in press):1–14.

Examples

```
n1 = 100; n2 = 100; pp = 500
set.seed(1)
X = matrix(rnorm(n1*pp), nrow=n1, ncol=pp)
Y = matrix(rnorm(n2*pp), nrow=n2, ncol=pp)
meantest.pe.comp(X,Y)
```

---

meantest.pe.fisher *Two-sample PE mean test for high-dimensional data via Fisher's combination*

Description

This function implements the two-sample PE covariance test via Fisher's combination. Suppose $\{\mathbf{X}_1, \ldots, \mathbf{X}_{n_1}\}$ are i.i.d. copies of $\mathbf{X}$, and $\{\mathbf{Y}_1, \ldots, \mathbf{Y}_{n_2}\}$ are i.i.d. copies of $\mathbf{Y}$. Let p_{CQ} and p_{CLX} denote the p-values associated with the l_2-norm-based covariance test (see `meantest.cq` for details) and the l_∞-norm-based covariance test (see `meantest.clx` for details), respectively. The PE covariance test via Fisher's combination is defined as

$$M_{Fisher} = -2\log(p_{CQ}) - 2\log(p_{CLX}).$$

It has been proved that with some regularity conditions, under the null hypothesis $H_{0m} : \boldsymbol{\mu}_1 = \boldsymbol{\mu}_2$, the two tests are asymptotically independent as $n_1, n_2, p \to \infty$, and therefore M_{Fisher} asymptotically converges in distribution to a χ_4^2 distribution. The asymptotic p-value is obtained by

$$p\text{-value} = 1 - F_{\chi_4^2}(M_{Fisher}),$$

where $F_{\chi_4^2}(\cdot)$ is the cdf of the χ_4^2 distribution.

Usage

```
meantest.pe.fisher(dataX,dataY)
```

Arguments

`dataX`	an n_1 by p data matrix
`dataY`	an n_2 by p data matrix

Value

`stat` the value of test statistic

`pval` the p-value for the test.

References

Chen, S. X. and Qin, Y. L. (2010). A two-sample test for high-dimensional data with applications to gene-set testing. *Annals of Statistics*, 38(2):808–835.

Cai, T. T., Liu, W., and Xia, Y. (2014). Two-sample test of high dimensional means under dependence. *Journal of the Royal Statistical Society: Series B: Statistical Methodology*, 76(2):349–372.

Examples

```
n1 = 100; n2 = 100; pp = 500
set.seed(1)
X = matrix(rnorm(n1*pp), nrow=n1, ncol=pp)
Y = matrix(rnorm(n2*pp), nrow=n2, ncol=pp)
meantest.pe.fisher(X,Y)
```

---

simultest — *Two-sample simultaneous tests on high-dimensional mean vectors and covariance matrices*

Description

This function implements six two-sample simultaneous tests on high-dimensional mean vectors and covariance matrices. Let $\mathbf{X} \in \mathbb{R}^p$ and $\mathbf{Y} \in \mathbb{R}^p$ be two p-dimensional populations with mean vectors $(\boldsymbol{\mu}_1, \boldsymbol{\mu}_2)$ and covariance matrices $(\boldsymbol{\Sigma}_1, \boldsymbol{\Sigma}_2)$, respectively. The problem of interest is the simultaneous inference on the equality of mean vectors and covariance matrices of the two populations:

$$H_0 : \boldsymbol{\mu}_1 = \boldsymbol{\mu}_2 \ \text{ and } \ \boldsymbol{\Sigma}_1 = \boldsymbol{\Sigma}_2.$$

Suppose $\{\mathbf{X}_1, \ldots, \mathbf{X}_{n_1}\}$ are i.i.d. copies of $\mathbf{X}$, and $\{\mathbf{Y}_1, \ldots, \mathbf{Y}_{n_2}\}$ are i.i.d. copies of $\mathbf{Y}$. We denote `dataX`=$(\mathbf{X}_1, \ldots, \mathbf{X}_{n_1})^\top \in \mathbb{R}^{n_1 \times p}$ and `dataY`=$(\mathbf{Y}_1, \ldots, \mathbf{Y}_{n_2})^\top \in \mathbb{R}^{n_2 \times p}$.

Usage

```
simultest(dataX, dataY, method='pe.fisher', delta_mean=NULL, delta_cov=NULL)
```

Arguments

`dataX`	an n_1 by p data matrix
`dataY`	an n_2 by p data matrix
`method`	the method type (default = `'pe.fisher'`); chosen from

- `'cauchy'`: the simultaneous test via Cauchy combination; see `simultest.cauchy` for details.

- 'chisq': the simultaneous test via chi-squared approximation; see simultest.chisq for details.
- 'fisher': the simultaneous test via Fisher's combination; see simultest.fisher for details.
- 'pe.cauchy': the PE simultaneous test via Cauchy combination; see simultest.pe.cauchy for details.
- 'pe.chisq': the PE simultaneous test via chi-squared approximation; see simultest.pe.chisq for details.
- 'pe.fisher': the PE simultaneous test via Fisher's combination; see simultest.pe.fisher for details.

delta_mean — the thresholding value used in the construction of the PE component for the mean test statistic. It is needed only in PE methods such as method='pe.cauchy', method='pe.chisq', and method='pe.fisher'; see simultest.pe.cauchy, simultest.pe.chisq, and simultest.pe.fisher for details. The default is NULL.

delta_cov — the thresholding value used in the construction of the PE component for the covariance test statistic. It is needed only in PE methods such as method='pe.cauchy', method='pe.chisq', and method='pe.fisher'; see simultest.pe.cauchy, simultest.pe.chisq, and simultest.pe.fisher for details. The default is NULL.

Value

method the method type

stat the value of test statistic

pval the p-value for the test.

References

Chen, S. X. and Qin, Y. L. (2010). A two-sample test for high-dimensional data with applications to gene-set testing. *Annals of Statistics*, 38(2):808–835.

Li, J. and Chen, S. X. (2012). Two sample tests for high-dimensional covariance matrices. *The Annals of Statistics*, 40(2):908–940.

Yu, X., Li, D., and Xue, L. (2022). Fisher's combined probability test for high-dimensional covariance matrices. *Journal of the American Statistical Association*, (in press):1–14.

Yu, X., Li, D., Xue, L., and Li, R. (2022). Power-enhanced simultaneous test of high-dimensional mean vectors and covariance matrices with application to gene-set testing. *Journal of the American Statistical Association*, (in press):1–14.

Examples

```
n1 = 100; n2 = 100; pp = 500
set.seed(1)
X = matrix(rnorm(n1*pp), nrow=n1, ncol=pp)
Y = matrix(rnorm(n2*pp), nrow=n2, ncol=pp)
simultest(X,Y)
```

simultest.cauchy *Two-sample simultaneous test using Cauchy combination*

Description

This function implements the two-sample simultaneous test on high-dimensional mean vectors and covariance matrices using Cauchy combination. Suppose $\{\mathbf{X}_1, \dots, \mathbf{X}_{n_1}\}$ are i.i.d. copies of $\mathbf{X}$, and $\{\mathbf{Y}_1, \dots, \mathbf{Y}_{n_2}\}$ are i.i.d. copies of $\mathbf{Y}$. Let p_{CQ} and p_{LC} denote the p-values associated with the l_2-norm-based mean test proposed in Chen and Qin (2010) (see `meantest.cq` for details) and the l_2-norm-based covariance test proposed in Li and Chen (2012) (see `covtest.lc` for details), respectively. The simultaneous test statistic via Cauchy combination is defined as

$$C_{n_1,n_2} = \frac{1}{2}\tan((0.5 - p_{CQ})\pi) + \frac{1}{2}\tan((0.5 - p_{LC})\pi).$$

It has been proved that with some regularity conditions, under the null hypothesis $H_0 : \boldsymbol{\mu}_1 = \boldsymbol{\mu}_2$ and $\boldsymbol{\Sigma}_1 = \boldsymbol{\Sigma}_2$, the two tests are asymptotically independent as $n_1, n_2, p \to \infty$, and therefore C_{n_1,n_2} asymptotically converges in distribution to a standard Cauchy distribution. The asymptotic p-value is obtained by

$$p\text{-value} = 1 - F_{Cauchy}(C_{n_1,n_2}),$$

where $F_{Cauchy}(\cdot)$ is the cdf of the standard Cauchy distribution.

Usage

```
simultest.cauchy(dataX,dataY)
```

Arguments

`dataX`	an n_1 by p data matrix
`dataY`	an n_2 by p data matrix

Value

`stat` the value of test statistic

`pval` the p-value for the test.

References

Chen, S. X. and Qin, Y. L. (2010). A two-sample test for high-dimensional data with applications to gene-set testing. *Annals of Statistics*, 38(2):808–835.

Li, J. and Chen, S. X. (2012). Two sample tests for high-dimensional covariance matrices. *The Annals of Statistics*, 40(2):908–940.

Yu, X., Li, D., Xue, L., and Li, R. (2022). Power-enhanced simultaneous test of high-dimensional mean vectors and covariance matrices with application to gene-set testing. *Journal of the American Statistical Association*, (in press):1–14.

Examples

```
n1 = 100; n2 = 100; pp = 500
set.seed(1)
X = matrix(rnorm(n1*pp), nrow=n1, ncol=pp)
Y = matrix(rnorm(n2*pp), nrow=n2, ncol=pp)
simultest.cauchy(X,Y)
```

`simultest.chisq` *Two-sample simultaneous test using chi-squared approximation*

Description

This function implements the two-sample simultaneous test on high-dimensional mean vectors and covariance matrices using chi-squared approximation. Suppose $\{\mathbf{X}_1, \ldots, \mathbf{X}_{n_1}\}$ are i.i.d. copies of $\mathbf{X}$, and $\{\mathbf{Y}_1, \ldots, \mathbf{Y}_{n_2}\}$ are i.i.d. copies of $\mathbf{Y}$. Let $M_{CQ}/\hat{\sigma}_{M_{CQ}}$ denote the l_2-norm-based mean test statistic proposed in Chen and Qin (2010) (see `meantest.cq` for details), and let $T_{LC}/\hat{\sigma}_{T_{LC}}$ denote the l_2-norm-based covariance test statistic proposed in Li and Chen (2012) (see `covtest.lc` for details). The simultaneous test statistic via chi-squared approximation is defined as

$$S_{n_1,n_2} = M_{CQ}^2/\hat{\sigma}_{M_{CQ}}^2 + T_{LC}^2/\hat{\sigma}_{T_{LC}}^2.$$

It has been proved that with some regularity conditions, under the null hypothesis $H_0 : \boldsymbol{\mu}_1 = \boldsymbol{\mu}_2$ and $\boldsymbol{\Sigma}_1 = \boldsymbol{\Sigma}_2$, the two tests are asymptotically independent as $n_1, n_2, p \to \infty$, and therefore S_{n_1,n_2} asymptotically converges in distribution to a χ_2^2 distribution. The asymptotic p-value is obtained by

$$p\text{-value} = 1 - F_{\chi_2^2}(S_{n_1,n_2}),$$

where $F_{\chi_2^2}(\cdot)$ is the cdf of the χ_2^2 distribution.

Usage

```
simultest.chisq(dataX,dataY)
```

Arguments

`dataX`	n1 by p data matrix
`dataY`	n2 by p data matrix

Value

`stat` the value of test statistic

`pval` the p-value for the test.

References

Yu, X., Li, D., Xue, L., and Li, R. (2022). Power-enhanced simultaneous test of high-dimensional mean vectors and covariance matrices with application to gene-set testing. *Journal of the American Statistical Association*, (in press):1–14.

Examples

```
n1 = 100; n2 = 100; pp = 500
set.seed(1)
X = matrix(rnorm(n1*pp), nrow=n1, ncol=pp)
Y = matrix(rnorm(n2*pp), nrow=n2, ncol=pp)
simultest.chisq(X,Y)
```

`simultest.fisher` *Two-sample simultaneous test using Fisher's combination*

Description

This function implements the two-sample simultaneous test on high-dimensional mean vectors and covariance matrices using Fisher's combination. Suppose $\{\mathbf{X}_1, \ldots, \mathbf{X}_{n_1}\}$ are i.i.d. copies of $\mathbf{X}$, and $\{\mathbf{Y}_1, \ldots, \mathbf{Y}_{n_2}\}$ are i.i.d. copies of $\mathbf{Y}$. Let p_{CQ} and p_{LC} denote the p-values associated with the l_2-norm-based mean test proposed in Chen and Qin (2010) (see `meantest.cq` for details) and the l_2-norm-based covariance test proposed in Li and Chen (2012) (see `covtest.lc` for details), respectively. The simultaneous test statistic via Fisher's combination is defined as

$$J_{n_1,n_2} = -2\log(p_{CQ}) - 2\log(p_{LC}).$$

It has been proved that with some regularity conditions, under the null hypothesis $H_0 : \boldsymbol{\mu}_1 = \boldsymbol{\mu}_2$ and $\boldsymbol{\Sigma}_1 = \boldsymbol{\Sigma}_2$, the two tests are asymptotically independent as $n_1, n_2, p \to \infty$, and therefore J_{n_1,n_2} asymptotically converges in distribution to a χ_4^2 distribution. The asymptotic p-value is obtained by

$$p\text{-value} = 1 - F_{\chi_4^2}(J_{n_1,n_2}),$$

where $F_{\chi_4^2}(\cdot)$ is the cdf of the χ_4^2 distribution.

Usage

```
simultest.fisher(dataX,dataY)
```

Arguments

`dataX`	an n_1 by p data matrix
`dataY`	an n_2 by p data matrix

Value

`stat` the value of test statistic

`pval` the p-value for the test.

References

Chen, S. X. and Qin, Y. L. (2010). A two-sample test for high-dimensional data with applications to gene-set testing. *Annals of Statistics*, 38(2):808–835.

Li, J. and Chen, S. X. (2012). Two sample tests for high-dimensional covariance matrices. *The Annals of Statistics*, 40(2):908–940.

Yu, X., Li, D., Xue, L., and Li, R. (2022). Power-enhanced simultaneous test of high-dimensional mean vectors and covariance matrices with application to gene-set testing. *Journal of the American Statistical Association*, (in press):1–14.

Examples

```
n1 = 100; n2 = 100; pp = 500
set.seed(1)
X = matrix(rnorm(n1*pp), nrow=n1, ncol=pp)
Y = matrix(rnorm(n2*pp), nrow=n2, ncol=pp)
simultest.fisher(X,Y)
```

`simultest.pe.cauchy` *Two-sample PE simultaneous test using Cauchy combination*

Description

This function implements the two-sample PE simultaneous test on high-dimensional mean vectors and covariance matrices using Cauchy combination. Suppose $\{\mathbf{X}_1, \ldots, \mathbf{X}_{n_1}\}$ are i.i.d. copies of $\mathbf{X}$, and $\{\mathbf{Y}_1, \ldots, \mathbf{Y}_{n_2}\}$ are i.i.d. copies of $\mathbf{Y}$. Let M_{PE} and T_{PE} denote the PE mean test statistic and PE covariance test statistic, respectively. (see `meantest.pe.comp` and `covtest.pe.comp` for details). Let p_m and p_c denote their respective p-values. The PE simultaneous test statistic via Cauchy combination is defined as

$$C_{PE} = \frac{1}{2}\tan((0.5 - p_m)\pi) + \frac{1}{2}\tan((0.5 - p_c)\pi).$$

It has been proved that with some regularity conditions, under the null hypothesis $H_0 : \boldsymbol{\mu}_1 = \boldsymbol{\mu}_2$ and $\boldsymbol{\Sigma}_1 = \boldsymbol{\Sigma}_2$, the two tests are asymptotically independent as $n_1, n_2, p \to \infty$, and therefore C_{PE} asymptotically converges in distribution to a standard Cauchy distribution. The asymptotic p-value is obtained by

$$p\text{-value} = 1 - F_{Cauchy}(C_{PE}),$$

where $F_{Cauchy}(\cdot)$ is the cdf of the standard Cauchy distribution.

Usage

```
simultest.pe.cauchy(dataX,dataY,delta_mean=NULL,delta_cov=NULL)
```

Arguments

dataX	an n_1 by p data matrix
dataY	an n_2 by p data matrix
delta_mean	a scalar; the thresholding value used in the construction of the PE component for mean test; see meantest.pe.comp for details.
delta_cov	a scalar; the thresholding value used in the construction of the PE component for covariance test; see covtest.pe.comp for details.

Value

stat the value of test statistic

pval the p-value for the test.

References

Yu, X., Li, D., Xue, L., and Li, R. (2022). Power-enhanced simultaneous test of high-dimensional mean vectors and covariance matrices with application to gene-set testing. *Journal of the American Statistical Association*, (in press):1–14.

Examples

```
n1 = 100; n2 = 100; pp = 500
set.seed(1)
X = matrix(rnorm(n1*pp), nrow=n1, ncol=pp)
Y = matrix(rnorm(n2*pp), nrow=n2, ncol=pp)
simultest.pe.cauchy(X,Y)
```

---

simultest.pe.chisq *Two-sample PE simultaneous test using chi-squared approximation*

Description

This function implements the two-sample PE simultaneous test on high-dimensional mean vectors and covariance matrices using chi-squared approximation. Suppose $\{\mathbf{X}_1, \ldots, \mathbf{X}_{n_1}\}$ are i.i.d. copies of $\mathbf{X}$, and $\{\mathbf{Y}_1, \ldots, \mathbf{Y}_{n_2}\}$ are i.i.d. copies of $\mathbf{Y}$. Let M_{PE} and T_{PE} denote the PE mean test statistic and PE covariance test statistic, respectively. (see meantest.pe.comp and covtest.pe.comp for details). The PE simultaneous test statistic via chi-squared approximation is defined as

$$S_{PE} = M_{PE}^2 + T_{PE}^2.$$

It has been proved that with some regularity conditions, under the null hypothesis $H_0 : \boldsymbol{\mu}_1 = \boldsymbol{\mu}_2$ and $\boldsymbol{\Sigma}_1 = \boldsymbol{\Sigma}_2$, the two tests are asymptotically independent as $n_1, n_2, p \to \infty$, and therefore S_{PE} asymptotically converges in distribution to a χ_2^2 distribution. The asymptotic p-value is obtained by

$$p\text{-value} = 1 - F_{\chi_2^2}(S_{PE}),$$

where $F_{\chi_2^2}(\cdot)$ is the cdf of the χ_2^2 distribution.

Usage

```
simultest.pe.chisq(dataX,dataY,delta_mean=NULL,delta_cov=NULL)
```

Arguments

`dataX`	an n_1 by p data matrix
`dataY`	an n_2 by p data matrix
`delta_mean`	a scalar; the thresholding value used in the construction of the PE component for mean test; see `meantest.pe.comp` for details.
`delta_cov`	a scalar; the thresholding value used in the construction of the PE component for covariance test; see `covtest.pe.comp` for details.

Value

`stat` the value of test statistic

`pval` the p-value for the test.

References

Yu, X., Li, D., Xue, L., and Li, R. (2022). Power-enhanced simultaneous test of high-dimensional mean vectors and covariance matrices with application to gene-set testing. *Journal of the American Statistical Association*, (in press):1–14.

Examples

```
n1 = 100; n2 = 100; pp = 500
set.seed(1)
X = matrix(rnorm(n1*pp), nrow=n1, ncol=pp)
Y = matrix(rnorm(n2*pp), nrow=n2, ncol=pp)
simultest.pe.chisq(X,Y)
```

`simultest.pe.fisher` *Two-sample PE simultaneous test using Fisher's combination*

Description

This function implements the two-sample PE simultaneous test on high-dimensional mean vectors and covariance matrices using Fisher's combination. Suppose $\{\mathbf{X}_1, \ldots, \mathbf{X}_{n_1}\}$ are i.i.d. copies of $\mathbf{X}$, and $\{\mathbf{Y}_1, \ldots, \mathbf{Y}_{n_2}\}$ are i.i.d. copies of $\mathbf{Y}$. Let M_{PE} and T_{PE} denote the PE mean test statistic and PE covariance test statistic, respectively. (see `meantest.pe.comp` and `covtest.pe.comp` for details). Let p_m and p_c denote their respective p-values. The PE simultaneous test statistic via Fisher's combination is defined as

$$J_{PE} = -2\log(p_m) - 2\log(p_c).$$

It has been proved that with some regularity conditions, under the null hypothesis $H_0 : \boldsymbol{\mu}_1 = \boldsymbol{\mu}_2$ and $\boldsymbol{\Sigma}_1 = \boldsymbol{\Sigma}_2$, the two tests are asymptotically independent as $n_1, n_2, p \to \infty$, and therefore J_{PE} asymptotically converges in distribution to a χ_4^2 distribution. The asymptotic p-value is obtained by

$$p\text{-value} = 1 - F_{\chi_4^2}(J_{PE}),$$

where $F_{\chi_4^2}(\cdot)$ is the cdf of the χ_4^2 distribution.

Usage

```
simultest.pe.fisher(dataX,dataY,delta_mean=NULL,delta_cov=NULL)
```

Arguments

dataX	an n_1 by p data matrix
dataY	an n_2 by p data matrix
delta_mean	a scalar; the thresholding value used in the construction of the PE component for mean test; see meantest.pe.comp for details.
delta_cov	a scalar; the thresholding value used in the construction of the PE component for covariance test; see covtest.pe.comp for details.

Value

stat the value of test statistic

pval the p-value for the test.

References

Yu, X., Li, D., Xue, L., and Li, R. (2022). Power-enhanced simultaneous test of high-dimensional mean vectors and covariance matrices with application to gene-set testing. *Journal of the American Statistical Association*, (in press):1–14.

Examples

```
n1 = 100; n2 = 100; pp = 500
set.seed(1)
X = matrix(rnorm(n1*pp), nrow=n1, ncol=pp)
Y = matrix(rnorm(n2*pp), nrow=n2, ncol=pp)
simultest.pe.fisher(X,Y)
```

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