Package ‘FarmTest’

Type Package
Title Factor-Adjusted Robust Multiple Testing
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Description Performs robust multiple testing for means in the presence of known and unknown latent factors presented in Fan et al.(2019) "FarmTest: Factor-Adjusted Robust Multiple Testing With Approximate False Discovery Control" <doi:10.1080/01621459.2018.1527700>. Implements a series of adaptive Huber methods combined with fast data-drive tuning schemes proposed in Ke et al.(2019) "User-Friendly Covariance Estimation for Heavy-Tailed Distributions" <doi:10.1214/19-STS711> to estimate model parameters and construct test statistics that are robust against heavy-tailed and/or asymmetric error distributions. Extensions to two-sample simultaneous mean comparison problems are also included. As by-products, this package contains functions that compute adaptive Huber mean, covariance and regression estimators that are of independent interest.

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Author Xiaoou Pan [aut, cre],
Yuan Ke [aut],
Wen-Xin Zhou [aut]

Maintainer Xiaoou Pan <xip024@ucsd.edu>
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Description
FarmTest package performs robust multiple testing for means in the presence of known and unknown latent factors (Fan et al, 2019). It implements a series of adaptive Huber methods combined with fast data-drive tuning schemes (Wang et al, 2020; Ke et al, 2019) to estimate model parameters and construct test statistics that are robust against heavy-tailed and/or assymetric error distributions. Extensions to two-sample simultaneous mean comparison problems are also included. As by-products, this package also contains functions that compute adaptive Huber mean, covariance and regression estimators that are of independent interest.

Details
See its GitHub page https://github.com/XiaoouPan/FarmTest for details.

References

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**farm.test**

*Factor-adjusted robust multiple testing*

**Description**

This function conducts factor-adjusted robust multiple testing (FarmTest) for means of multivariate data proposed in Fan et al. (2019) via a tuning-free procedure.

**Usage**

```r
farm.test(
  X,
  fX = NULL,
  KX = -1,
  Y = NULL,
  fY = NULL,
  KY = -1,
  h0 = NULL,
  alternative = c("two.sided", "less", "greater"),
  alpha = 0.05,
  p.method = c("bootstrap", "normal"),
  nBoot = 500
)
```

**Arguments**

- **X**: An *n* by *p* data matrix with each row being a sample.
- **fX**: An *optional* factor matrix with each column being a factor for *X*. The number of rows of *fX* and *X* must be the same.
- **KX**: An *optional* positive number of factors to be estimated for *X* when *fX* is not specified. *KX* cannot exceed the number of columns of *X*. If *KX* is not specified or specified to be negative, it will be estimated internally. If *KX* is specified to be 0, no factor will be adjusted.
- **Y**: An *optional* data matrix used for two-sample FarmTest. The number of columns of *X* and *Y* must be the same.
- **fY**: An *optional* factor matrix for two-sample FarmTest with each column being a factor for *Y*. The number of rows of *fY* and *Y* must be the same.
An optional positive number of factors to be estimated for Y for two-sample FarmTest when \( f_Y \) is not specified. \( KY \) cannot exceed the number of columns of Y. If \( KY \) is not specified or specified to be negative, it will be estimated internally. If \( KY \) is specified to be 0, no factor will be adjusted.

An optional \( p \)-vector of true means, or difference in means for two-sample FarmTest. The default is a zero vector.

An optional character string specifying the alternate hypothesis, must be one of "two.sided" (default), "less" or "greater".

An optional level for controlling the false discovery rate. The value of \( \alpha \) must be between 0 and 1. The default value is 0.05.

An optional character string specifying the method to calculate p-values when \( f_X \) is known or when \( K_X = 0 \), possible options are multiplier bootstrap or normal approximation. It must be one of "bootstrap"(default) or "normal".

An optional positive integer specifying the size of bootstrap sample, only available when \( p \).method = "bootstrap". The default value is 500.

Details

For two-sample FarmTest, means, stdDev, loadings, eigenVal, eigenRatio, nfactors and n will be lists of items for sample X and Y separately.

\( \text{alternative} = "\text{greater}\" \) is the alternative that \( \mu > \mu_0 \) for one-sample test or \( \mu_X > \mu_Y \) for two-sample test.

Setting \( p \).method = "bootstrap" for factor-known model will slow down the program, but it will achieve lower empirical FDP than setting \( p \).method = "normal".

Value

An object with S3 class farm.test containing the following items will be returned:

- means: Estimated means, a vector with length \( p \).
- stdDev: Estimated standard deviations, a vector with length \( p \). It’s not available for bootstrap method.
- loadings: Estimated factor loadings, a matrix with dimension \( p \) by \( K \), where \( K \) is the number of factors.
- eigenVal: Eigenvalues of estimated covariance matrix, a vector with length \( p \). It’s only available when factors \( f_X \) and \( f_Y \) are not given.
- eigenRatio: Ratios of eigenVal to estimate \( n \)Factors, a vector with length \( \min(n,p)/2 \). It’s only available when number of factors \( K_X \) and \( K_Y \) are not given.
- nfactors: Estimated or input number of factors, a positive integer.
- tStat: Values of test statistics, a vector with length \( p \). It’s not available for bootstrap method.
- pValues: P-values of tests, a vector with length \( p \).
- pAdjust: Adjusted p-values of tests, a vector with length \( p \).
- significant: Boolean values indicating whether each test is significant, with 1 for significant and 0 for non-significant, a vector with length \( p \).
reject Indices of tests that are rejected. It will show "no hypotheses rejected" if none of the tests are rejected.

type Indicator of whether factor is known or unknown.
n Sample size.
p Data dimension.
h0 Null hypothesis, a vector with length p.
alpha $\alpha$ value.
alternative Alternative hypothesis.

References


See Also

print.farm.test, summary.farm.test and plot.farm.test.

Examples

```r
n = 20
p = 50
K = 3
muX = rep(0, p)
muX[1:5] = 2
epsilonX = matrix(rnorm(p * n, 0, 1), nrow = n)
BX = matrix(runif(p * K, -2, 2), nrow = p)
FX = matrix(rnorm(K * n, 0, 1), nrow = n)
X = rep(1, n) %*% t(muX) + fX %*% t(BX) + epsilonX
# One-sample FarmTest with two sided alternative
output = farm.test(X)
# One-sample FarmTest with one sided alternative
output = farm.test(X, alternative = "less")
# One-sample FarmTest with known factors
output = farm.test(X, fX = fX)
```
# Two-sample FarmTest

```
muY = rep(0, p)
muY[1:5] = 4
epsilonY = matrix(rnorm(p * n, 0, 1), nrow = n)
BY = matrix(runif(p * K, -2, 2), nrow = p)
fY = matrix(rnorm(K * n, 0, 1), nrow = n)
Y = rep(1, n) %*% t(muY) + fY %*% t(BY) + epsilonY
output = farm.test(X, Y = Y)
```

**huber.cov**  
_Tuning-free Huber-type covariance estimation_

**Description**

The function calculates adaptive Huber-type covariance estimator from a data sample, with robustification parameter \( \tau \) determined by a tuning-free principle. For the input matrix \( X \), both low-dimension \( (p < n) \) and high-dimension \( (p > n) \) are allowed.

**Usage**

```
huber.cov(X)
```

**Arguments**

- **X**: An \( n \) by \( p \) data matrix.

**Value**

A \( p \) by \( p \) Huber-type covariance matrix estimator will be returned.

**References**


**See Also**

- `huber.mean` for tuning-free Huber mean estimation and `huber.reg` for tuning-free Huber regression.

**Examples**

```
n = 100
d = 50
X = matrix(rt(n * d, df = 3), n, d) / sqrt(3)
Sigma = huber.cov(X)
```
**huber.mean**

Tuning-free Huber mean estimation

**Description**

The function calculates adaptive Huber mean estimator from a data sample, with robustification parameter \( \tau \) determined by a tuning-free principle.

**Usage**

```r
huber.mean(X)
```

**Arguments**

- **X**: An \( n \)-dimensional data vector.

**Value**

A Huber mean estimator will be returned.

**References**


**See Also**

- `huber.cov` for tuning-free Huber-type covariance estimation and `huber.reg` for tuning-free Huber regression.

**Examples**

```r
n = 10000
X = rt(n, 2) + 2
mu = huber.mean(X)
```
huber.reg  Tuning-free Huber regression

Description
The function conducts Huber regression from a data sample, with robustification parameter \( \tau \) determined by a tuning-free principle.

Usage
huber.reg(X, Y, method = c("standard", "adaptive"))

Arguments
- **X**: An \( n \) by \( p \) design matrix, where \( p < n \).
- **Y**: A continuous response with length \( n \).
- **method**: An optional character string specifying the method to calibrate the robustification parameter \( \tau \). Two choices are "standard" (default) and "adaptive". See Wang et al. (2020) for details.

Value
A coefficients estimator with length \( p + 1 \) will be returned.

References

See Also
huber.mean for tuning-free Huber mean estimation and huber.cov for tuning-free Huber-type covariance estimation.

Examples
```r
n = 200
d = 10
beta = rep(1, d)
X = matrix(rnorm(n * d), n, d)
err = rnorm(n)
Y = 1 + X * beta + err
beta.hat = huber.reg(X, Y)
```
plot.farm.test

Plot function of FarmTest

Description
This is the plot function of S3 objects with class "farm.test". It produces the histogram of estimated means.

Usage
## S3 method for class 'farm.test'
plot(x, ...)

Arguments
x A farm.test object.
...
Further arguments passed to or from other methods.

Details
For two-sample FarmTest, the histogram is based on the difference: estimated means of sample X - estimated means of sample Y.

Value
No variable will be returned, but a histogram of estimated means will be presented.

See Also
farm.test, print.farm.test and summary.farm.test.

Examples
n = 50
p = 100
K = 3
muX = rep(0, p)
muX[1:5] = 2
epsilonX = matrix(rnorm(p * n, 0, 1), nrow = n)
BX = matrix(runif(p * K, -2, 2), nrow = p)
FX = matrix(rnorm(K * n, 0, 1), nrow = n)
X = rep(1, n) %*% t(muX) + fX %*% t(BX) + epsilonX
output = farm.test(X)
plot(output)
print.farm.test  

Description

This is the print function of S3 objects with class "farm.test".

Usage

## S3 method for class 'farm.test'
print(x, ...)

Arguments

x  
A farm.test object.
...  
Further arguments passed to or from other methods.

Value

No variable will be returned, but a brief summary of FarmTest will be displayed.

See Also

farm.test, summary.farm.test and plot.farm.test.

Examples

n = 50
p = 100
K = 3
muX = rep(0, p)
muX[1:5] = 2
epsilonX = matrix(rnorm(p * n, 0, 1), nrow = n)
BX = matrix(runif(p * K, -2, 2), nrow = p)
FX = matrix(rnorm(K * n, 0, 1), nrow = n)
X = rep(1, n) %*% t(muX) + FX %*% t(BX) + epsilonX
output = farm.test(X)
print(output)
Description

This is the summary function of S3 objects with class "farm.test".

Usage

```r
## S3 method for class 'farm.test'
summary(object, ...)
```

Arguments

- `object`: A `farm.test` object.
- `...`: Further arguments passed to or from other methods.

Details

For two-sample FarmTest, the first column is the difference: estimated means of sample \( X \) - estimated means of sample \( Y \).

Value

A data frame including the estimated means, p-values, adjusted p-values and significance for all the features will be presented.

See Also

`farm.test`, `print.farm.test` and `plot.farm.test`.

Examples

```r
n = 50
p = 100
K = 3
muX = rep(0, p)
mux[1:5] = 2
epsilonX = matrix(rnorm(p * n, 0, 1), nrow = n)
BX = matrix(runif(p * K, -2, 2), nrow = p)
FX = matrix(rnorm(K * n, 0, 1), nrow = n)
X = rep(1, n) * t(muX) + FX * t(BX) + epsilonX
output = farm.test(X)
summary(output)
```
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