Package 'MVTests'

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Title Multivariate Hypothesis Tests

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Description Multivariate hypothesis tests and the confidence intervals. It can be used to test the hypothesizes about mean vector or vectors (one-sample, two independent samples, paired samples), covariance matrix (one or more matrices), and the correlation matrix. Moreover, it can be used for robust Hotelling T^2 test at one sample case in high dimensional data. For this package, we have benefited from the studies Rencher (2003), Nel and Merwe (1986) <DOI:10.1080/03610928608829342>, Tatlidil (1996), Tsagris (2014), Villasenor Alva and Estrada (2009) <DOI:10.1080/03610920802474465>.

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Bcov   *Bartlett's Test for One Sample Covariance Matrix*

Description

Bcov function tests whether the covariance matrix is equal to a given matrix or not.

Usage

```
Bcov(data, Sigma)
```

Arguments

data   a data frame.

Sigma   The covariance matrix in NULL hypothesis.

Details

This function computes Bartlett's test statistic for the covariance matrix of one sample.

Value

a list with 3 elements:

ChiSquare   The value of Test Statistic

df   The Chi-Square statistic's degree of freedom

p.value   p value

Author(s)

Hasan BULUT <hasan.bulut@omu.edu.tr>

References

Rencher, A. C. (2003). Methods of multivariate analysis (Vol. 492). John Wiley & Sons.

Examples

```
data(iris)
S<-matrix(c(5.71,-0.8,-0.6,-0.5,-0.8,4.09,-0.74,-0.54,-0.6,
     -0.74,7.38,-0.18,-0.5,-0.54,-0.18,8.33),ncol=4,nrow=4)
result <- Bcov(data=iris[,1:4],Sigma=S)
summary(result)
```

BoxM   *Box's M Test*

Description

BoxM function tests whether the covariance matrices of independent samples are equal or not.

Usage

```
BoxM(data, group)
```

Arguments

data   a data frame.

group   grouping vector.

Details

This function computes Box-M test statistic for the covariance matrices of independent samples. The hypotheses are defined as H0:The Covariance matrices are homogeneous and H1:The Covariance matrices are not homogeneous

Value

a list with 3 elements:

ChiSquare   The value of Test Statistic

df   The Chi-Square statistic's degree of freedom

p.value   p value

Author(s)

Hasan BULUT <hasan.bulut@omu.edu.tr>

References

Rencher, A. C. (2003). Methods of multivariate analysis (Vol. 492). John Wiley & Sons.

Examples

```
data(iris)
results <- BoxM(data=iris[,1:4],group=iris[,5])
summary(results)
```

Bsper *Bartlett's Sphericity Test*

Description

Bsper function tests whether a correlation matrix is equal to the identity matrix or not.

Usage

```
Bsper(data)
```

Arguments

data   a data frame.

Details

This function computes Bartlett's test statistic for Sphericity Test. The hypotheses are H0:R is equal to I and H1:R is not equal to I.

Value

a list with 4 elements:

ChiSquare	The value of Test Statistic
df	The Chi-Square statistic's degree of freedom
p.value	p value
R	Correlation matrix

Author(s)

Hasan BULUT <hasan.bulut@omu.edu.tr>

References

Tatlidil, H. (1996). Uygulamali Cok Degiskenli Istatistiksel Yontemler. Cem Web.

Examples

```
data(iris)
results <- Bsper(data=iris[,1:4])
summary(results)
```

Coated	*Coated*

Description

The data set is given in Table 5.3 in Rencher (2003). The data set consists of 2 variables (Depth and Number), 2 treatments and 15 observations. The first column of the data is Location numbers.

Usage

```
Coated
```

Format

A data frame with 15 rows and 5 columns. The columns are as follows:

Location The location numbers of observations.

Coating1.Depth1 The Depth values in the first treatment

Coating1.Number1 The Number values in the first treatment

Coating2.Depth2 The Depth values in the second treatment

Coating2.Number2 The Number values in the second treatment

Source

The data set is used in the book entitled Methods of Multivariate Analysis (Rencher,2003).

References

Rencher, A. C. (2003). Methods of multivariate analysis (Vol. 492). John Wiley & Sons.

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iris	*Iris Data*

Description

The Iris dataset is consists of 4 variables, 3 groups and 150 observations. The last column of the data is Iris species.

Usage

```
iris
```

Format

A data frame with 150 rows and 5 columns. The columns are as follows:

Sepal.Length The Sepal length values of iris flowers
Sepal.Width The Sepal width values of iris flowers
Petal.Length The Petal length values of iris flowers
Petal.Width The Petal width values of iris flowers
Species The species of iris flowers

Source

https://archive.ics.uci.edu/ml/datasets/Iris

Mpaired   *Multivariate Paired Test*

Description

Mpaired function computes the value of test statistic based on Hotelling T Square approach in multivariate paired data sets.

Usage

```
Mpaired(T1, T2)
```

Arguments

T1   The first treatment data.
T2   The second treatment data.

Details

This function computes one sample Hotelling T^2 statistics for paired data sets.

Value

a list with 7 elements:

HT2   The value of Hotelling T^2 Test Statistic
F   The value of F Statistic
df   The F statistic's degree of freedom
p.value   p value
Descriptive1   The descriptive statistics of the first treatment
Descriptive2   The descriptive statistics of the second treatment
Descriptive.Difference
                   The descriptive statistics of the differences

Author(s)

Hasan BULUT <hasan.bulut@omu.edu.tr>

References

Rencher, A. C. (2003). Methods of multivariate analysis (Vol. 492). John Wiley & Sons.

Examples

```
data(Coated)
X<-Coated[,2:3]; Y<-Coated[,4:5]
result <- Mpaired(T1=X,T2=Y)
summary(result)
```

OneSampleHT2   *One Sample Hotelling T^2 Test*

Description

OneSampleHT2 computes one sample Hotelling T^2 statistics and gives confidence intervals

Usage

```
OneSampleHT2(data, mu0, alpha = 0.05)
```

Arguments

data   a data frame.

mu0   mean vector that is used to test whether population mean parameter is equal to
                it.

alpha   Significance Level that will be used for confidence intervals. default alpha=0.05.

Details

This function computes one sample Hotelling T^2 statistics that is used to test whether population
mean vector is equal to a vector given by a user. When H0 is rejected, this function computes
confidence intervals for all variables.

Value

a list with 7 elements:

HT2   The value of Hotelling T^2 Test Statistic

F   The value of F Statistic

df   The F statistic's degree of freedom

p.value   p value

CI	The lower and upper limits of confidence intervals obtained for all variables
alpha	The alpha value using in confidence intervals
Descriptive	Descriptive Statistics

Author(s)

Hasan BULUT <hasan.bulut@omu.edu.tr>

References

Rencher, A. C. (2003). Methods of multivariate analysis (Vol. 492). John Wiley & Sons.

Tatlidil, H. (1996). Uygulamali Cok Degiskenli Istatistiksel Yontemler. Cem Web.

Examples

```
data(iris)

mean0<-c(6,3,1,0.25)
result <- OneSampleHT2(data=iris[1:50,-5],mu0=mean0,alpha=0.05)
summary(result)
```

RHT2   *Robust Hotelling T^2 Test for One Sample in High Dimensional Data*

Description

Robust Hotelling T^2 Test for One Sample in high Dimensional Data

Usage

```
RHT2(data, mu0, alpha = 0.75, d, q)
```

Arguments

data	the data. It must be matrix or data.frame.
mu0	the mean vector which will be used to test the null hypothesis.
alpha	numeric parameter controlling the size of the subsets over which the determinant is minimized. Allowed values are between 0.5 and 1 and the default is 0.75.
d	the constant in Equation (11) in the study by Bulut (2021).
q	the second degree of freedom value of the approximate F distribution in Equation (11) in the study by Bulut (2021).

Details

RHT2 function performs a robust Hotelling T^2 test in high dimensional test based on the minimum regularized covariance determinant estimators. This function needs the q and d values. These values can be obtained simRHT2 function. For more detailed information, you can see the study by Bulut (2021).

Value

a list with 3 elements:

T2	The Robust Hotelling T^2 value in high dimensional data
Fval	The F value based on T2
pval	The p value based on the approximate F distribution

Author(s)

Hasan BULUT <hasan.bulut@omu.edu.tr>

References

Bulut, H (2021). A robust Hotelling test statistic for one sample case in high dimensional data, Communication in Statistics: Theory and Methods.

Examples

```
library(rrcov)
data(octane)
mu.clean<-colMeans(octane[-c(25,26,36,37,38,39),])

RHT2(data=octane,mu0=mu.clean,alpha=0.84,d=1396.59,q=1132.99)
```

RobCat	*Robust CAT Algorithm*

Description

RobCat computes p value based on robust CAT algorithm to compare two means vectors under multivariate Behrens-Fisher problem.

Usage

```
RobCat(X, Y, M = 1000, alpha = 0.75)
```

Arguments

X	a matrix or data frame for first group.
Y	a matrix or data frame for second group.
M	iteration number and the default is 1000.
alpha	numeric parameter controlling the size of the subsets over which the determinant is minimized; roughly alpha*n, observations are used for computing the determinant. Allowed values are between 0.5 and 1 and the default is 0.75.

Details

This function computes p value based on robust CAT algorithm to compare two means vectors under multivariate Behrens-Fisher problem. When p value<0.05, it means the difference of two mean vectors is significant statistically.

Value

a list with 2 elements:

Cstat   Calculated value of test statistic

pval   The p value

Author(s)

Hasan BULUT <hasan.bulut@omu.edu.tr>

Examples

```
data(iris)
RobCat(X=iris[1:20,-5],Y=iris[81:100,-5])
```

RperT2   *Robust Permutation Hotelling T^2 Test in High Dimensional Data*

Description

Robust Permutation Hotelling T^2 Test for Two Independent Samples in high Dimensional Data

Usage

```
RperT2(X1, X2, alpha = 0.75, N = 100)
```

Arguments

X1   the data matrix for the first group. It must be matrix or data.frame.

X2   the data matrix for the first group. It must be matrix or data.frame.

alpha   numeric parameter controlling the size of the subsets over which the determinant is minimized. Allowed values are between 0.5 and 1 and the default is 0.75.

N   the permutation number

Details

RperT2 function performs a robust permutation Hotelling T^2 test for two independent samples in high dimensional test based on the minimum regularized covariance determinant estimators.

Value

a list with 2 elements:

T2	The calculated value of Robust Hotelling T^2 statistic based on MRCD estimations
p.value	p value obtained from test process

Author(s)

Hasan BULUT <hasan.bulut@omu.edu.tr>

References

Bulut, H (2023). A robust Hotelling test statistic for two samples case in high dimensional data. (Unpublished)

Examples

```
library(rrcov)
x<-mvtnorm::rmvnorm(n=10,sigma=diag(20),mean=rep(0,20))
y<-mvtnorm::rmvnorm(n=10,sigma=diag(20),mean=rep(1,20))
RperT2(X1=x,X2=y)$p.value
```

---

simRHT2	*Monte Carlo Simulation to obtain d and q constants for RHT2 function*

Description

Monte Carlo Simulation to obtain d and q constants for RHT2 function

Usage

```
simRHT2(n, p, nrep = 500)
```

Arguments

n	the sample size
p	the number of variables
nrep	the number of iteration. The default value is 500.

Details

simRHT2 function computes d and q constants to construct an approximate F distribution of robust Hotelling T^2 statistic in high dimensional data. These constants are used in RHT2 function. For more detailed information, you can see the study by Bulut (2021).

Value

a list with 2 elements:

q   The q value

d   The d value

Author(s)

Hasan BULUT <hasan.bulut@omu.edu.tr>

References

Bulut, H (2021). A robust Hotelling test statistic for one sample case in highdimensional data, Communication in Statistics: Theory and Methods.

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summary.MVTests   *Summarizing Results in MVTests Package*

Description

summary.MVTests function summarizes of results of functions in this package.

Usage

```
## S3 method for class 'MVTests'
summary(object, ...)
```

Arguments

object   an object of class MVTests.

...   additional parameters.

Details

This function prints a summary of the results of multivariate hypothesis tests in the MVTests package.

Value

the input object is returned silently.

Author(s)

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Examples

```
# One Sample Hotelling T Square Test
data(iris)
X<-iris[1:50,1:4]
mean0<-c(6,3,1,0.25)
result.onesample <- OneSampleHT2(data=X,mu0=mean0,alpha=0.05)
summary(result.onesample)

#Two Independent Sample Hotelling T Square Test
data(iris)
G<-c(rep(1,50),rep(2,50))
result.twosamples <- TwoSamplesHT2(data=iris[1:100,1:4],group=G,alpha=0.05)
summary(result.twosamples)

#Box's M Test
data(iris)
result.BoxM <- BoxM(data=iris[,1:4],group=iris[,5])
summary(result.BoxM)

#Barlett's Test of Sphericity
data(iris)
result.Bsper <- Bsper(data=iris[,1:4])
summary(result.Bsper)

#Bartlett's Test for One Sample Covariance Matrix
data(iris)
S<-matrix(c(5.71,-0.8,-0.6,-0.5,-0.8,4.09,-0.74,-0.54,-0.6,-0.74,
         7.38,-0.18,-0.5,-0.54,-0.18,8.33),ncol=4,nrow=4)
result.bcov<- Bcov(data=iris[,1:4],Sigma=S)
summary(result.bcov)
```

TR2   *Robust Hotelling T^2 Test Statistic*

Description

Robust Hotelling T^2 Test Statistic for Two Independent Samples in high Dimensional Data

Usage

```
TR2(x1, x2, alpha = 0.75)
```

Arguments

x1	the data matrix for the first group. It must be matrix or data.frame.
x2	the data matrix for the first group. It must be matrix or data.frame.
alpha	numeric parameter controlling the size of the subsets over which the determinant is minimized. Allowed values are between 0.5 and 1 and the default is 0.75.

Details

TR2 function calculates the robust Hotelling T^2 test statistic for two independent samples in high dimensional data based on the minimum regularized covariance determinant estimators.

Value

a list with 2 elements:

TR2   The calculated value of Robust Hotelling T^2 statistic based on MRCD estimations

Author(s)

Hasan BULUT <hasan.bulut@omu.edu.tr>

References

Bulut, H (2023). A robust Hotelling test statistic for two samples case in high dimensional data. (Unpublished)

Examples

```
library(rrcov)
x<-mvtnorm::rmvnorm(n=10,sigma=diag(20),mean=rep(0,20))
y<-mvtnorm::rmvnorm(n=10,sigma=diag(20),mean=rep(1,20))
TR2(x1=x,x2=y)
```

TwoSamplesHT2   *Two Independent Samples Hotelling T^2 Test*

Description

TwoSamplesHT2 function computes Hotelling T^2 statistic for two independent samples and gives confidence intervals.

Usage

```
TwoSamplesHT2(data, group, alpha = 0.05, Homogenity = TRUE)
```

Arguments

data   a data frame.

group   a group vector consisting of 1 and 2 values.

alpha   Significance Level that will be used for confidence intervals. default=0.05

Homogenity   a logical argument. If sample covariance matrices are homogeneity,then Homogenity=TRUE.
                Otherwise Homogenity=FALSE The homogeneity of covariance matrices can be
                investigated with BoxM function.

Details

This function computes two independent samples Hotelling T^2 statistics that is used to test whether two population mean vectors are equal to each other. When H0 is rejected, this function computes confidence intervals for all variables to determine variable(s) affecting on rejection decision. Moreover, when covariance matrices are not homogeneity, the approach proposed by D. G. Nel and V. D. Merwe (1986) is used.

Value

a list with 8 elements:

HT2	The value of Hotelling T^2 Test Statistic
F	The value of F Statistic
df	The F statistic's degree of freedom
p.value	p value
CI	The lower and upper limits of confidence intervals obtained for all variables
alpha	The alpha value using in confidence intervals
Descriptive1	Descriptive Statistics for the first group
Descriptive2	Descriptive Statistics for the second group

Author(s)

Hasan BULUT <hasan.bulut@omu.edu.tr>

References

Rencher, A. C. (2003). Methods of multivariate analysis (Vol. 492). John Wiley & Sons.

Tatlidil, H. (1996). Uygulamali Cok Degiskenli Istatistiksel Yontemler. Cem Web.

D.G. Nel & C.A. Van Der Merwe (1986) A solution to the multivariate behrens fisher problem, Communications in Statistics:Theory and Methods, 15:12, 3719-3735

Examples

```
data(iris)
G<-c(rep(1,50),rep(2,50))
# When covariances matrices are homogeneity
results1 <- TwoSamplesHT2(data=iris[1:100,1:4],group=G,alpha=0.05)
summary(results1)
# When covariances matrices are not homogeneity
results2 <- TwoSamplesHT2(data=iris[1:100,1:4],group=G,Homogenity=FALSE)
summary(results2)
```

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