Package 'MSQC'

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Title Multivariate Statistical Quality Control

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Depends R (>= 3.1.0), graphics, stats, utils

Imports rgl

Description This is a toolkit for multivariate process monitoring. It computes several multivariate control charts e.g. Hotelling, Chi-squared, MEWMA, MCUSUM and Generalized Variance. Ten didactic datasets are included. It includes some techniques for assessing multivariate normality e.g. Mardia's, Royston's and Henze-Zirkler's tests. Please, see the NEWS file for the latest changes in the package.

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`MSQC-package` *Multivariate Statistical Quality Control*

Description

It computes several multivariate control charts such as: Hotelling, Chi-squared, MEWMA, MCUSUM and Generalized Variance. Ten didactic datasets are included. It includes some tools for assessing multivariate normality: Mardia's, Royston's and Henze-Zirkler's tests.

Details

Package:	MSQC
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Author(s)

Edgar Santos-Fernandez

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References

Bodden, K.M., Rigdon, S.E.: A Program for Approximating the In Control ARL for the MEWMA Chart. *Journal of Quality Technology* 31,(1999)

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Mason, R.L., Tracy, N.D., Young, J.C.: Decomposition of T square for multivariate control chart interpretation. *Journal of Quality Technology* 27, (1995)

Mason, R.L., Young, J.C.: Multivariate Statistical Process Control with Industrial Application, 1 ed. *Society for Industrial and Applied Mathematics*, (2001)

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Pignatiello, J., Runger, G.: Comparisons of Multivariate CUSUM Charts. *Journal of Quality Technology* 22(3), (1990)

Prabhu, S.S., Runger, G.C.: Designing a multivariate EWMA control chart. *Journal of Quality Technology* 29, (1997)

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Santos-Fernandez, E.: Multivariate Statistical Quality Control Using R. *Springer*, 14, (2013)

Sullivan, J.H., Woodall, W.H.: A Comparison of Multivariate Quality Control Charts for Individual Observations. *Journal of Quality Technology* 28(4) (1996)

Tracy, N., Young, Mason, R.: Multivariate Control Charts for Individual Observations. *Journal of Quality Technology* 24 (1992)

Woodall, W.H., Ncube, M.M.: Multivariate CUSUM Quality Control Procedures. *Technometrics* 3(3), (1985)

See Also

MPCI package https://cran.r-project.org/package=MPC

Examples

```
data(dowel1)
mult.chart(dowel1, type = "chi", alpha = 0.05)

#Phase I
data(carbon1)
mult.chart(type = "t2", carbon1)

#Phase II
Xmv <- mult.chart(carbon1, type = "t2") $Xmv
S <- mult.chart(carbon1, type = "t2") $covariance
colm <- nrow(carbon1)

data(carbon2)
mult.chart(carbon2, type = "t2", Xmv = Xmv, S = S, colm = colm)

# (MEWMA) in Phase II
Xmv <- mult.chart(carbon1, type = "t2") $Xmv
S <- mult.chart(carbon1, type = "t2") $covariance
mult.chart(type = "mewma", carbon2, Xmv = Xmv, S = S)


#Multivariate Cumulative Sum (MCUSUM) in Phase I
mult.chart(type = "mcusum", carbon2)
mult.chart(type = "mcusum2", carbon2)
```

---

archery1 *Target archery dataset during the ranking round (used as Phase I)*

Description

It consists of a stage in which the archer shoots 72 arrows. The information is given in x and y coordinates.

Usage

```
data(archery1)
```

Format

An array of dimension (24 x 2 x 3).

`"x-coordinate"` x coordinate

`"y-coordinate"` y coordinate

Examples

```
data(archery1)
## maybe str(archery1) ; plot(archery1) ...
```

`archery2` *Target archery dataset during the elimination stage (used as Phase II)*

Description

It consists of a stage in which the archer shoots 52 arrows. The information is given in x and y coordinates.

Usage

```
data(archery1)
```

Format

An array of (18 x 2 x 3).

`"x-coordinate"` x coordinate

`"y-coordinate"` y coordinate

Examples

```
data(archery1)
## maybe str(archery1) ; plot(archery1) ...
```

bimetal1 *Bimetal dataset during the Phase I*

Description

The dataset contains measurements of the deflection, the curvature, the resistivity and the hardness in low and high expansion sides, from brass and steel bimetal thermostats. The manufacturing process is assumed to be "in-control".

Usage

```
data(bimetal1)
```

Format

A matrix of (28 x 5)

`"deflection"` the deflection level in 10^-6 1/K

`"curvature"` the curvature level in 10^-6 1/K

`"resistivity "` the resistivity level in 10 ^-1ohm x mm^2 / m

`"hardness low expansion side"` the hardness of the low expansion side in 10 N/mm^2

`"hardness high expansion side"` the hardness of the high expansion side in 10 N/mm^3

Examples

```
data(bimetal1)
## maybe str(bimetal1) ; plot(bimetal1) ...
```

bimetal2 *Bimetal dataset during the Phase II*

Description

The dataset contains measurements of the deflection, the curvature, the resistivity and the hardness in low and high expansion sides, from brass and steel bimetal thermostats. These observations represent the Phase II.

Usage

```
data(bimetal2)
```

Format

A matrix of (28 x 5)

`"deflection"` the deflection level in 10^-6 1/K

`"curvature"` the curvature level in 10^-6 1/K

`"resistivity "` the resistivity level in 10 ^-1ohm x mm^2 / m

`"hardness low expansion side"` the hardness of the low expansion side in 10 N/mm^2

`"hardness high expansion side"` the hardness of the high expansion side in 10 N/mm^3

Examples

```
data(bimetal2)
## maybe str(bimetal2) ; plot(bimetal2) ...
```

---

carbon1 *Carbon fiber tubing during the Phase I*

Description

Three quality characteristics (inner diameter, thickness and length) are measured in a specific carbon fiber tube. This dataset consist of 30 samples of size 8 were collected and the process is assumed to be stable.

Usage

```
data(carbon1)
```

Format

An array of dimensions 30 x 3 x 8.

`"inner diameter"` is the inner diameter of the tubes

`"thickness"` is the thickness

`"length"` is the length

Examples

```
data(carbon1)
## maybe str(carbon1) ; plot(carbon1) ...
```

carbon2 *Carbon fiber tubing during the Phase II*

Description

Three quality characteristics (inner diameter, thickness and length) are measured in a specific carbon fiber tube. This dataset consist of 25 samples of size 8. This dataset is considered as the Phase II.

Usage

```
data(carbon2)
```

Format

An array of dimensions 25 x 3 x 8.

`"inner diameter"` is the inner diameter

`"thickness"` is the thickness

`"length"` is the length

Examples

```
data(carbon2)
## maybe str(carbon2) ; plot(carbon2) ...
```

covariance *Sample covariance*

Description

It computes the sample covariance in presence of rational subgroups or for individual observations according to Sullivan and Woodall (1996) and Holmes and Mergen (1993)

Usage

```
covariance(x, stat, method, ...)
```

Arguments

`x`	matrix or array containing the quality characteristics.
`stat`	is the statistics
`method`	is the method used in individual observation case.
`...`	other parameters

Note

In individual observations case (n = 1) use for default the Sullivan and Woodall (1996) proposal

Author(s)

Edgar Santos-Fernandez

References

Holmes, D.S., Mergen, A.E.: Improving the performance of T-square control chart. *Quality Engineering* 5(4), 619-625 (1993)

Sullivan, J.H., Woodall, W.H.: A Comparison of Multivariate Quality Control Charts for Individual Observations. *Journal of Quality Technology* 28(4) (1996)

Examples

```
# individual case
data(bimetal1)
covariance(bimetal1, method = "sw")
covariance(bimetal1, method = "hm")

# rational subgroup case
data(carbon1)
covariance(carbon1)
```

DAGOSTINO *D'Agostino test*

Description

It performs the D'Agostino test of univariate normality

Usage

```
DAGOSTINO(data)
```

Arguments

```
data
```

Author(s)

This test is a modification of the original written in Spanish by Peter Mandeville

References

DAgostino, R., Pearson, E.S.: Tests for Departure from Normality. Empirical Results for the Distributions of b2 and sqrt(b1). *Biometrika* 60(3),(1973)

D'Agostino, R.B.: Transformation to normality of the null distribution of g1. *Biometrika* 57(3), (1970)

D'Agostino, R.B., Belanger, A., Jr, R.B.D.A.: A suggestion for using powerful and informative tests of normality. *The American Statistician* 44(4),(1990)

See Also

Chi-squared, Anderson-Darling, Kolmogorov-Smirnov, Jarque-Bera and Shapiro-Wilks tests

Examples

```
data(bimetal1)
for (i in 1 : 5){
DAGOSTINO(bimetal1[,i])
}
```

---

dowel1 *Dowel pin dataset for the Phase I*

Description

Diameter and length of a dowel pin.

Usage

```
data(dowel1)
```

Format

A data frame with 40 observations.

`diameter` a numeric vector

`length` a numeric vector

Examples

```
data(dowel1)
## maybe str(dowel1) ; plot(dowel1) ...
```

dowel2 *Dowel pin dataset for the Phase II*

Description

Diameter and length of a dowel pin

Usage

```
data(dowel2)
```

Format

A data frame with 32 observations.

`diameter` a numeric vector

`length` a numeric vector

Examples

```
data(dowel2)
## maybe str(dowel2) ; plot(dowel2) ...
```

ellip *confidence ellipsoid*

Description

It makes a confidence ellipsoid.

Usage

```
ellip(type = c("chi", "t2"), x, Xmv, S, phase=1, alpha=0.01, method="sw", colm,...)
```

Arguments

`type`	is the type of ellipsoid to constructs (chi or t2)
`x`	matrix containing the quality characteristics.
`Xmv`	is the mean vector
`S`	is the sample covariance matrix
`phase`	is the Phase (1 or 2) and will determine the UCL to use. Only the values phase = 1 or 2 are allowed.
`alpha`	is the significance level (0.01 for default)
`method`	is the method to compute S.
`colm`	is the number of samples (m), which is only used in Hotelling control chart (Phase II)
`...`	other parameters

Author(s)

Edgar Santos-Fernandez

Examples

```
data(dowel1)
ellip(type = "chi", dowel1, alpha = 0.01)
```

`gen.var` *Generalized Variance Control Chart*

Description

It computes the Generalized Variance Control Chart

Usage

```
gen.var(x, ...)
```

Arguments

`x`	an array containing the quality characteristics
`...`	

Details

Notice that this is a control chart for rational subgroups only and n must be higher than p

Author(s)

Edgar Santos-Fernandez

References

Montgomery, D.C.: Introduction to Statistical Quality Control, 5 ed. *John Wiley & Sons*, (2004)

Examples

```
data("carbon1")
gen.var(carbon1)
```

glass1 *Dataset of a glass manufacturing process during the Phase I*

Description

Three variables measured with the aim to establish the in-control situation

Usage

```
data(glass1)
```

Format

An array of (32 x 3 x 5).

`"Var1"` a numeric vector

`"Var2"` a numeric vector

`"Var3"` a numeric vector

Examples

```
data(glass1)
## maybe str(glass1) ; plot(glass1) ...
```

glass2 *Dataset of a glass manufacturing process during the Phase II*

Description

It contains the measurements of three quality characteristics

Usage

```
data(glass2)
```

Format

An array of (25 x 3 x 5).

`"Var1"` a numeric vector

`"Var2"` a numeric vector

`"Var3"` a numeric vector

Examples

```
data(glass2)
## maybe str(glass2) ; plot(glass2) ...
```

HZ.test *Henze-Zirkler test*

Description

It computes the Henze-Zirkler test for assessing multivariate normality

Usage

```
HZ.test(data)
```

Arguments

```
data
```

Author(s)

Patrick Farrell, Matias Salibian-Barrera, Kat Naczk

References

Henze, N., Zirkler, B.: A Class of Invariant Consistent Tests for Multivariate Normality. Communications in Statistics - Theory and Methods 19(10), 3595-3617 (1990)

See Also

Royston.test MardiaTest

Examples

```
data(bimetal1)
HZ.test(bimetal1)
```

indust1 *Industrial dataset collected during the Phase I*

Description

A bivariate industrial process

Usage

```
data(indust1)
```

Format

A data frame containing 28 observations.

`Var1` a numeric vector

`Var2` a numeric vector

Examples

```
data(indust1)
## maybe str(indust1) ; plot(indust1) ...
```

`indust2` *Industrial dataset collected in Phase II*

Description

A bivariate industrial process

Usage

```
data(indust2)
```

Format

A data frame containing 35 observations.

`Var1` a numeric vector

`Var2` a numeric vector

Examples

```
data(indust2)
## maybe str(indust2) ; plot(indust2) ...
```

kulpa *Coordinates of the pitches called "strike" by umpire Ron Kulpa*

Description

The dataset was selected from a Tampa Bay game on July 10, 2011

Usage

```
data(kulpa)
```

Format

A data frame with 113 observations on the following 2 variables.

`px` the x-axis is horizontally oriented

`pz` the z-axis is the vertically oriented

Examples

```
data(kulpa)
```

larg.ellip *Largest ellipsoid*

Description

It builds the largest ellipsoid centered at the Target.

Usage

```
larg.ellip(LSL,USL,n=25,box=FALSE,add=TRUE,xlim=xlim,ylim=ylim,zlim=zlim,
xlab="xlab",ylab="ylab",zlab="zlab",col=2,alpha=0.2,...)
```

Arguments

`LSL`	is the lower specification limit
`USL`	is the upper specification limit
`n`	
`box`	
`add`	
`xlim`	
`ylim`	
`zlim`	

xlab
ylab
zlab
col
alpha
...

Author(s)

These codes are based on a function written by Duncan Murdoch (rgl package)

Examples

#

MardiaTest *Mardia test*

Description

It computes the Mardia test for assessing multivariate normality

Usage

```
MardiaTest(data)
```

Arguments

data

Author(s)

Scott Ulman

References

Mardia, K.V.: Measures of multivariate skewness and kurtosis. Biometrika 57,(1970) Mardia, K.V.: Applications of some measures of multivariate skewness and kurtosis for testing normality and robustness studies. Sankhya 36,(1974)

See Also

HZ.test Royston.test

Examples

```
data(bimetal1)
MardiaTest(bimetal1)
```

mech1 *A mechanical process (Phase I)*

Description

Seven variables collected from a mechanical process

Usage

```
data(mech1)
```

Format

The format is: An array of (45 x 7).

Examples

```
data(mech1)
```

mech2 *A mechanical process (Phase II)*

Description

Seven variables collected from a mechanical process

Usage

```
data(mech2)
```

Format

The format is: An array of (50 x 7).

Examples

```
data(mech2)
```

`mult.chart` *Multivariate Control Chart*

Description

It computes several multivariate control charts: Hotelling, Chi-squared, MEWMA, MCUSUM and Generalized Variance chart.

Usage

```
mult.chart(type = c("chi", "t2", "mewma", "mcusum", "mcusum2"), x, Xmv,
 S, colm, alpha = 0.01, lambda = 0.1, k = 0.5, h = 5.5, phase = 1,
 method = "sw", ...)
```

Arguments

`type`	refers to the name of the type of chart e.g. type="chi", type="t2", type="mewma" or type="mcusum"
`x`	matrix or array of the quality characteristics.
`Xmv`	is the mean vector. It is only specified for Phase II or when the parameters of the distribution are given.
`S`	is the sample covariance matrix. It is only used for Phase II or when the parameters of the distribution are known.
`colm`	is the number of samples (m). It will only be used for the Hotelling control chart (Phase II).
`alpha`	it is the significance level (0.01 for default).
`lambda`	is the smoothing constant for the MEWMA chart. Only the value 0.1, 0.2,...,0.9 are allowed.
`k`	is a constant used in MCUSUM chart. Frequently k = 0.5.
`h`	is a constant used in MCUSUM chart. Usually h = 5.5.
`phase`	Refers to the Phase, say phase = 1 or 2. It is used to select the type of UCL.
`method`	is the method employed to compute the covariance matrix for the case of individual observations. Two methods are used "sw" for compute it according to Sullivan and Woodall (1996) and "hm" to compute it using Holmes and Mergen (1993) approach.
`...`	other parameters

Author(s)

Edgar Santos-Fernandez

References

Bodden, K.M., Rigdon, S.E.: A Program for Approximating the In Control ARL for the MEWMA Chart. *Journal of Quality Technology* 31,(1999)

Borror, C.M., Montgomery, D.C., Runger, G.C.: Robustness of the EWMA control chart to non normality. *Journal of Quality Technology* 31(3), (1999)

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Runger, G.C., Alt, F.B., Montgomery, D.C.: Contributors to a multivariate SPC chart signal. *Communications in Statistics: Theory and Methods* 25, (1996)

Sullivan, J.H., Woodall, W.H.: A Comparison of Multivariate Quality Control Charts for Individual Observations. *Journal of Quality Technology* 28(4) (1996)

Tracy, N., Young, Mason, R.: Multivariate Control Charts for Individual Observations. *Journal of Quality Technology* 24 (1992)

Woodall, W.H., Ncube, M.M.: Multivariate CUSUM Quality Control Procedures. *Technometrics* 3(3), (1985)

Examples

```
data(dowel1)
mult.chart(dowel1, type = "chi", alpha = 0.05)

#Phase I
data(carbon1)
mult.chart(type = "t2", carbon1)

#Phase II
Xmv <- mult.chart(carbon1, type = "t2") $Xmv
S <- mult.chart(carbon1, type = "t2") $covariance
colm<-nrow(carbon1)

data(carbon2)
mult.chart(carbon2, type = "t2", Xmv = Xmv, S = S, colm = colm)

# (MEWMA) in Phase II
Xmv <- mult.chart(carbon1, type = "t2") $Xmv
S <- mult.chart(carbon1, type = "t2") $covariance
mult.chart(type = "mewma", carbon2, Xmv = Xmv, S = S)


#Multivariate Cumulative Sum (MCUSUM) in Phase I
mult.chart(type = "mcusum", carbon2)
mult.chart(type = "mcusum2", carbon2)
```

`prism` *Draws a rectangular prism*

Description

This function draws a rectangular prism using three-dimensional limits

Usage

```
prism(LSL = LSL, USL = USL, add = TRUE, xlim = xlim, ylim = ylim, zlim = zlim, ...)
```

Arguments

`LSL`	is the lower specification limit
`USL`	is the upper specification limit
`add`	
`xlim`	xlim
`ylim`	ylim
`zlim`	zlim
`...`	additional parameters

Author(s)

Edgar Santos Fernandez

Examples

```
require(rgl)
LSL <- c( 0.60, 0.30, 49.00)
USL <- c(1.40, 1.70, 51.00)
prism(LSL, USL, add = TRUE, col = "#D55E00" )
```

---

proc.reg *Process region*

Description

It computes the process region

Usage

```
proc.reg(x, alpha = 0.0027, ...)
```

Arguments

x	a matrix of quality characteristics
alpha	it is the significance level (0.0027 for default)
...	other parameters

Author(s)

Edgar Santos-Fernandez

Examples

```
data(dowel1)
proc.reg(dowel1, alpha = 0.01)
```

`Royston.test` *Royston test*

Description

It computes the (Royston 1992) Test for assessing multivariate normality

Usage

```
Royston.test(data)
```

Arguments

`data`

Author(s)

Patrick Farrell, Matias Salibian-Barrera, Kat Naczk

References

Royston, J.P.: An Extension of Shapiro and Wilk' s W Test for Normality to Large Samples. Applied Statistics 31(2),(1982)

Royston, J.P.: Some Techniques for Assessing Multivarate Normality Based on the Shapiro Wilk W. Journal of the Royal Statistical Society. Series C (Applied Statistics) 32(2), (1983)

Royston, J.P.: Approximating the Shapiro Wilk W Test for non normality. Statistics and Computing 2(3), (1992)

Royston, J.P.: Remark AS R94: A remark on Algorithm AS 181: The W test for normality. Journal of the Royal Statistical Society. Series C (Applied Statistics) 44(4), (1995)

See Also

MardiaTest HZ.test

Examples

```
data(bimetal1)
Royston.test(bimetal1)
```

rskewed *Right skewed dataset*

Description

It is a right-skewed bivariate dataset

Usage

```
data(rskewed)
```

Format

The dimensions are 30x2

Examples

```
data(rskewed)
## maybe str(rskewed) ; plot(rskewed) ...
```

sabathia.ind *Individual observations from the MLB pitcher C.C. Sabathia from the game on July 10, 2011.*

Description

The dataset was selected from the game against Tampa Bay on July 10, 2011. It is composed by individual observations.

Usage

```
data(sabathia.ind)
```

Format

A data frame with 23 observations on the following 3 variables.

`px` is the x-axis horizontally oriented

`pz` is the z-axis vertically oriented

Examples

```
data(sabathia.ind)
```

sabathia1 *A pitching log of C.C. Sabathia on July 10, 2011.*

Description

The dataset is from the game against Tampa Bay on July 10, 2011. It contains the mean of the rational subgroup.

Usage

```
data(sabathia1)
```

Format

A data frame with 23 observations.

`px` the x-axis horizontally oriented

`pz` the z-axis vertically oriented

`start speed` is the starting speed of the fastball

Examples

```
data(sabathia1)
```

sabathia2 *A pitching log of C.C. Sabathia on August 12, 2011*

Description

The dataset is from the game against Tampa Bay on August 12, 2011

Usage

```
data(sabathia2)
```

Format

A data frame with 26 observations.

`px` the x-axis horizontally oriented

`pz` the z-axis vertically oriented

`start speed` is the starting speed of the fastball

Examples

```
data(sabathia2)
```

water1 *A water quality test (Phase I)*

Description

It consists of five variables (pH, phosphates (mg/L), nitrates (mg/L), dissolved oxygen and total solids (mg/L)) measured in a water quality test

Usage

```
data(water1)
```

Format

The format is: is a matrix (30 x 5)

Examples

```
data(water1)
```

water2 *A water quality test (Phase II)*

Description

It consists on five variables (pH, phosphates (mg/L), nitrates (mg/L), dissolved oxygen and total solids (mg/L)) measured in a water quality test

Usage

```
data(water2)
```

Format

The format is: is a matrix (25 x 5)

Examples

```
data(water2)
```

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