Package 'PH1XBAR'

July 21, 2025

Type Package

Title Phase I Shewhart X-Bar Chart

Version 0.11.3

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Description The purpose of 'PH1XBAR' is to build a Phase I Shewhart control chart for the basic She-
whart, the variance components and the ARMA models in R for subgrouped and individ-
ual data. More de-
tails can be found: Yao and Chakraborti (2020) <doi:10.1002/qre.2793>, Yao and Chakraborti (2021) <doi:10.1080/0898211

License GPL-3

Encoding UTF-8

LazyData true

Depends R (>= 3.5.0)

Imports forecast, mvtnorm, pracma, VGAM

URL https://github.com/bolus123/PH1XBAR

RoxygenNote 7.3.2

NeedsCompilation no

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Repository CRAN

Date/Publication 2025-06-19 16:30:02 UTC

Contents

PH1XBAR-package   *PH1XBAR: Phase I Shewhart X-Bar Chart*

Description

The purpose of 'PH1XBAR' is to build a Phase I Shewhart control chart for the basic Shewhart, the variance components and the ARMA models in R for subgrouped and individual data. More details can be found: Yao and Chakraborti (2020) doi: 10.1002/qre.2793, Yao and Chakraborti (2021) doi: 10.1080/08982112.2021.1878220, and Yao et al. (2023) doi: 10.1080/00224065.2022.2139783.

The utility of this package is in building a Shewhart-type control chart based on new methods for subgrouped and individual data. The Phase I chart is based on the multivariate normal/t or ARMA process.

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References

Champ, C.W., and Jones, L.A. (2004) Designing Phase I X-bar charts with small sample sizes. Quality and Reliability Engineering International. 20(5), 497-510

Yao, Y., Hilton, C.W., and Chakraborti, S. (2017) Designing Phase I Shewhart X-bar charts: Extended tables and software. Quality and Reliability Engineering International. 33(8), 2667-2672.

Yao, Y., and Chakraborti, S. (2021). Phase I monitoring of individual normal data: Design and implementation. Quality Engineering, 33(3), 443-456.

Yao, Y., and Chakraborti, S. (2021). Phase I process monitoring: The case of the balanced one-way random effects model. Quality and Reliability Engineering International, 37(3), 1244-1265.

Yao, Y., Chakraborti, S., Yang, X., Parton, J., Lewis Jr, D., and Hudnall, M. (2023). Phase I control chart for individual autocorrelated data: application to prescription opioid monitoring. Journal of Quality Technology, 55(3), 302-317.

See Also

Useful links:

- <https://github.com/bolus123/PH1XBAR>

Examples

```
#Build a Phase I basic Shewhart control chart
data(grinder_data)
PH1XBAR(grinder_data, nsim=10)

# Build a Phase I individual control chart with an ARMA model
data(preston_data)
PH1ARMA(preston_data, nsim.process=10, nsim.coefs=10)
```

---

bore_diameter_data   *Bore diameter in manufacturing automotive driver gears*

Description

A dataset cotaining bore diameter measurements in mm

Usage

```
bore_diameter_data
```

Format

A matrix with 20 rows and 5 variables:

X1 Diameter measurement at Position 1

X2 Diameter measurement at Position 2

X3 Diameter measurement at Position 3

X4 Diameter measurement at Position 4

X5 Diameter measurement at Position 5

References

Wooluru, Yerriswamy, D. R. Swamy, and P. Nagesh. "THE PROCESS CAPABILITY ANALYSIS-A TOOL FOR PROCESS PERFORMANCE MEASURES AND METRICS-A CASE STUDY." International Journal for Quality Research 8.3 (2014).

---

getCC.ARMA   *get Phase I corrected charting constant with an ARMA model*

Description

get Phase I corrected charting constant with an ARMA model

Usage

```
getCC.ARMA(
  fap0 = 0.05,
  interval = c(1, 4),
  m = 50,
  order = c(1, 0),
  phi.vec = 0.5,
  theta.vec = NULL,
  case = "U",
  method = "MLE+MOM",
  nsim.coefs = 100,
  nsim.process = 1000,
  burn.in = 50,
  sim.type = "Recursive",
  verbose = FALSE
)
```

Arguments

fap0	nominal false Alarm Probabilty in Phase 1
interval	searching range of charting constants for the exact method
m	number of observations
order	order for ARMA(p, q) model
phi.vec	a vector of length p containing autoregressive coefficient(s). When case = 'K', the vector must have a length equal to the first value in the order. If no autoregressive coefficent presents, set phi.vec = NULL
theta.vec	a vector of length q containing moving-average coefficient(s). When case = 'K', the vector must have a length equal to the first value in the order. If no moving-average coefficent presents, set theta.vec = NULL
case	known or unknown case. When case = 'U', the parameters are estimated, when case = 'K', the parameters need to be input
method	estimation method for the control chart. When method = 'Method 3' is maximum likehood estimations plus method of moments. Other options are 'Method 1' which is pure MLE and 'Method 2' which is pure CSS.
nsim.coefs	number of simulation for coeficients. It is functional when double.sim = TRUE.
nsim.process	number of simulation for ARMA processes

burn.in	number of burn-ins. When burn.in = 0, the ECM gets involved. When burn.in is large enough, the ACM gets involved.
sim.type	type of simulation. When sim.type = 'Matrix', the simulation is generated using matrix computation. When sim.type = 'Recursive', the simulation is based on a recursion.
verbose	print diagnostic information about fap0 and the charting constant during the simulations for the exact method

Value

Object type double. The corrected charting constant.

Examples

```
# load the data in the package as an example
set.seed(12345)

# Calculate the charting constant using fap0 of 0.05, and 50 observations
getCC.ARMA(fap0=0.05, m=50, nsim.coefs=10, nsim.process=10)
```

---

getCC.XBAR   *Random Flexible Level Shift Model*

Description

get Phase I corrected charting constant

Usage

```
getCC.XBAR(
  m,
  fap0 = 0.05,
  var.est = c("S", "MR"),
  ub.cons = 1,
  method = c("exact", "BA"),
  interval = c(1, 4),
  nsim = 10000,
  nu = m - 1,
  lambda = 1,
  verbose = FALSE
)
```

Arguments

m	number of subgroups when the data are subgrouped or number of observations when the data are individual.
fap0	nominal False Alarm Probabilty in Phase 1
var.est	'S' - use mean-square-based estimator, 'MR' - use moving-range-based estimator
ub.cons	unbiasing constant
method	'exact' - calculate results using the exact method, 'BA' - calculate results using the Bonfferoni approximation
interval	searching range of charting constants for the exact method
nsim	number of simulation for the exact method
nu	degrees of freedom; When var.est = 'S', the degrees of freedom is that of the chi-squared distribution itself for the variance estimator. When var.est = 'MR', the degrees of freedom is that of the chi-squared distribution approximating to the actual distribution.
lambda	unbiasing constant for the chi-squared distribution approximation. When var.est = 'S', there is no need to do the unbiasing. When var.est = 'MR', the unbiasing constant needs to be used.
verbose	print diagnostic information about fap0 and the charting constant during the simulations for the exact method

Value

Object type double. The corrected charting constant.

Examples

```
set.seed(12345)

# Calculate the charting constant using 10 simulations and mean-square-based estimator
getCC.XBAR(fap0=0.05, m=20, nsim=10, var.est='S', verbose = TRUE)

# Calculate the charting constant using 10 simulations and moving-range-based estimator
getCC.XBAR(fap0=0.05, m=20, nsim=10, var.est='MR', verbose = TRUE)
```

---

grinder_data	*Thickness measurement of silicon wafer*

Description

A dataset containing the thickness measurements in nm at different positions on the silicon wafer

Usage

```
grinder_data
```

Format

A matrix with 30 rows and 5 variables:

pos1 Thickness measurement at Position 1 (outer circle)

pos2 Thickness measurement at Position 2 (outer circle)

pos3 Thickness measurement at Position 3 (middle circle)

pos4 Thickness measurement at Position 4 (middle circle)

pos5 Thickness measurement at Position 5 (inner circle)

References

Roes, Kit CB, and Ronald JMM Does. "Shewhart-type charts in nonstandard situations." Technometrics 37.1 (1995): 15-24

PH1ARMA   *Phase I individual control chart with an ARMA model*

Description

Build a Phase I individual control chart for the ARMA models. The charting constant is corrected by this approach.

Usage

```
PH1ARMA(
  X,
  cc = NULL,
  fap0 = 0.05,
  order = c(1, 0),
  plot.option = TRUE,
  interval = c(1, 4),
  case = "U",
  phi.vec = NULL,
  theta.vec = NULL,
  mu0 = NULL,
  sigma0 = NULL,
  method = "MLE+MOM",
  nsim.coefs = 100,
  nsim.process = 1000,
  burn.in = 50,
  sim.type = "Recursive",
  transform = "none",
```

```
    lambda = 1,
    standardize = FALSE,
    verbose = FALSE
)
```

Arguments

X	input and it must be a vector (m by 1)
cc	nominal Phase I charting constant. If this is given, the function will not re-compute the charting constant.
fap0	nominal false Alarm Probabilty in Phase I
order	order for ARMA(p, q) model
plot.option	- draw a plot for the process; TRUE - Draw a plot for the process, FALSE - Not draw a plot for the process
interval	searching range of charting constants for the exact method
case	known or unknown case. When case = 'U', the parameters are estimated, when case = 'K', the parameters need to be input
phi.vec	a vector of length p containing autoregressive coefficient(s). When case = 'K', the vector must have a length equal to the first value in the order. If no autoregressive coeffcent presents, set phi.vec = NULL
theta.vec	a vector of length q containing moving-average coefficient(s). When case = 'K', the vector must have a length equal to the first value in the order. If no moving-average coeffcent presents, set theta.vec = NULL
mu0	value of the IC process mean. When case = 'K', the value needs to be provided.
sigma0	value of the IC process standard deviation. When case = 'K', the value needs to be provided.
method	estimation method for the control chart. When method = 'MLE+MOM' is maximum likehood estimations plus method of moments. Other options are 'MLE' which is pure MLE and 'CSS' which is pure CSS.
nsim.coefs	number of simulation for coefficients.
nsim.process	number of simulation for ARMA processes
burn.in	number of burn-ins. When burn.in = 0, the simulated process is assumed to be in the initial stage. When burn.in is sufficiently large (e.g., the default value of 50), the simulated process is assumed to have reached a stable state.
sim.type	type of simulation. When sim.type = 'Recursive', the simulation is generated recursively, as in the ARMA model. When sim.type = 'Matrix', the simulation is generated using the covariance matrix among observations, derived from the relationship between the ARMA coefficient(s) and the partial autocorrelation(s). Note that sim.type = 'Matrix' is primarily used as a proof of concept and is not recommended for practical use due to its high computational cost.
transform	type of transformation. When transform = 'none', no transformation is performed. When transform = 'boxcox', the Box-Cox transformation is used. When transform = 'yeojohnson', the Yeo-Johnson transformation is used.
lambda	parameter used in the Box-Cox or Yeo-Johnson transformation.

standardize	Output standardized charting statistics instead of raw ones. When standardize = TRUE, the standardization is used. When standardize = FALSE, the standardization is not performed.
verbose	print diagnostic information about fap0 and the charting constant during the simulations for the exact method

Value

CL Object type double - central line

gamma Object type double - process variance estimate

cc Object type double - charting constant

order Object type integer - order for ARMA model

phi.vec Object type integer - values of autoregressors

theta.vec Object type integer - values of moving averages

LCL Object type double - lower charting limit

UCL Object type double - upper charting limit

CS Object type double - charting statistic

References

Yao, Y., Chakraborti, S., Yang, X., Parton, J., Lewis Jr, D., and Hudnall, M. (2023). Phase I control chart for individual autocorrelated data: application to prescription opioid monitoring. Journal of Quality Technology, 55(3), 302-317.

Examples

```
# load the data in the package as an example
data(preston_data)

# set number of simulations
nsim.process <- 10
nsim.coefs <- 10

# An example using the default setting whose fap0 = 0.1
PH1ARMA(preston_data, nsim.process = nsim.process, nsim.coefs = nsim.coefs)

# When users get an error message about the size of matrix,
# the function needs to use the alternative simulation type as follows
PH1ARMA(preston_data, fap0 = 0.05,
nsim.process = nsim.process, nsim.coefs = nsim.coefs, sim.type = 'Recursive')
```

PH1XBAR *Phase I X-bar control chart with a corrected charting constant*

Description

Build a Phase I Shewhart control chart for the variance components model if the data are subgrouped or for the basic Shewhart model if the data are individual. The charting constant is correted by this approach.

Usage

```
PH1XBAR(
  X,
  cc = NULL,
  fap0 = 0.05,
  var.est = c("S", "MR"),
  ub.option = TRUE,
  method = c("exact", "BA"),
  plot.option = TRUE,
  interval = c(1, 4),
  nsim = 10000,
  transform = "none",
  lambda = 1,
  standardize = FALSE,
  verbose = FALSE
)
```

Arguments

X	input and it must be a matrix (m by n) or a vector (m by 1)
cc	nominal Phase I charting constant. If this is given, the function will not recompute the charting constant.
fap0	nominal False Alarm Probabilty in Phase 1
var.est	'S' - use mean-square-based estimator, 'MR' - use moving-range-based estimator
ub.option	TRUE - the standard deviation estimator corrected by a unbiasing constant. For S, it is c4 and for MR, it is d2. FALSE - no unbiasing constant
method	'exact' - calculate results using the exact method, 'BA' - calculate results using the Bonfferoni approximation
plot.option	- draw a plot for the process; TRUE - Draw a plot for the process, FALSE - Not draw a plot for the process
interval	searching range of charting constants for the exact method
nsim	number of simulation for the exact method

transform	type of transformation. When transform = 'none', no transformation is performed. When transform = 'boxcox', the Box-Cox transformation is used. When transform = 'yeojohnson', the Yeo-Johnson transformation is used.
lambda	parameter used in the Box-Cox or Yeo-Johnson transformation.
standardize	Output standardized charting statistics instead of raw ones. When standardize = TRUE, the standardization is used. When standardize = FALSE, the standardization is not performed.
verbose	print diagnostic information about fap0 and the charting constant during the simulations for the exact method

Value

CL Object type double - central line

var.est Object type double - variance estimate

ub.cons Object type double - unbiasing constant

cc Object type double - charting constant

m Object type integer - number of subgroups when X is a matrix or number of observations when X is a vector

nu Object type integer - degrees of freedom; When var.est = 'S', the degrees of freedom is that of the chi-squared distribution itself for the variance estimator. When var.est = 'MR', the degrees of freedom is that of the chi-squared distribution approximating to the actual distribution.

lambda Object type integer - chi-squared unbiasing constant for the chi-squared distribution approximation

LCL Object type double - lower charting limit

UCL Object type double - upper charting limit

CS Object type double - charting statistic

References

Champ, C.W., and Jones, L.A. (2004) Designing Phase I X-bar charts with small sample sizes. Quality and Reliability Engineering International. 20(5), 497-510

Yao, Y., Hilton, C.W., and Chakraborti, S. (2017) Designing Phase I Shewhart X-bar charts: Extended tables and software. Quality and Reliability Engineering International. 33(8), 2667-2672.

Yao, Y., and Chakraborti, S. (2021). Phase I monitoring of individual normal data: Design and implementation. Quality Engineering, 33(3), 443-456.

Yao, Y., and Chakraborti, S. (2021). Phase I process monitoring: The case of the balanced one-way random effects model. Quality and Reliability Engineering International, 37(3), 1244-1265.

Examples

```
set.seed(12345)

# load the data in the package as an example
data(grinder_data)
```

```
# An example using a false alarm probability of 0.05, and 10 simulations
PH1XBAR(grinder_data, fap0 = 0.05, nsim=10, verbose=TRUE)
```

---

pistonring_data   *Pistonring data*

Description

A dataset containing piston ring data

Usage

```
pistonring_data
```

Format

A data frame with 25 rows and 5 variables:

X1 Observation 1 in subgroups

X2 Observation 2 in subgroups

X3 Observation 3 in subgroups

X4 Observation 4 in subgroups

X5 Observation 5 in subgroups

References

Montgomery, Douglas C. 2005. Introduction to Statistical Quality Control. John Wiley & Sons.

---

preston_data   *Prescription fentanyl consumption in Preston county, WV*

Description

A dataset containing prescription fentanyl consumption in Preston county, WV, measured using MME percapita. This is a subset from Rich et al. <doi: 10.21105/joss.02450>

Usage

```
preston_data
```

Format

A vector with 60 elements

References

Rich, S., Tran, A. B., Williams, A., Holt, J., Sauer, J., & Oshan, T. M. (2020). arcos and arcospy: R and Python packages for accessing the DEA ARCOS database from 2006-2014. Journal of Open Source Software, 5(53), 2450.

---

semiconductor_data   *Semiconductor data*

Description

A dataset cotaining the 151st feature in SECOM dataset

Usage

```
semiconductor_data
```

Format

A vector with 50 observations:

obs the 151st feature

References

McCann, Michael, and Adrian Johnston. 2008. "SECOM." UCI Machine Learning Repository. DOI: https://doi.org/10.24432/C54305.

---

snowfall_data   *Seasonal snowfall in inches in Minneapolis/St. Paul, MN*

Description

A dataset containing snowfalls measured in inches in Minneapolis/St. Paul, MN.

Usage

```
snowfall_data
```

Format

A data frame with 82 rows and 4 variables:

Year year of the snowfalls

jan snowfalls in January

feb snowfalls in February

mar snowfalls in March

References

Mukherjee, P. S. (2016). On phase II monitoring of the probability distributions of univariate continuous processes. Statistical Papers, 57(2), 539-562.

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