Package 'attrCUSUM'

December 28, 2016

Type Package

Title Tools for Attribute VSI CUSUM Control Chart

Version 0.1.0

Description An implementation of tools for design of attribute
variable sampling interval cumulative sum chart.
It currently provides information for monitoring of mean increase such as
average number of sample to signal, average time to signal,
a matrix of transient probabilities, suitable control limits when the data are
(zero inflated) Poisson/binomial distribution.
Functions in the tools can be easily applied to other count processes.
Also, tools might be extended to more complicated cumulative sum control chart.
We leave these issues as our perpetual work.

License GPL (>= 2)

LazyData TRUE

Depends R (>= 3.3.2)

Imports Rcpp (>= 0.12.8), stats (>= 3.3.2), utils (>= 3.3.2)

Suggests testthat (>= 1.0.2), knitr (>= 1.15.1), rmarkdown (>= 1.2)

RoxygenNote 5.0.1

VignetteBuilder knitr

LinkingTo Rcpp (>= 0.12.8), RcppArmadillo (>= 0.7.500.0.0)

NeedsCompilation yes

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Repository CRAN

Date/Publication 2016-12-28 17:18:36

R topics documented:

`attrCUSUM-package` *Tools for Attribute CUSUM Control Chart*

Description

An implementation of tools for design of attribute VSI CUSUM chart. It currently provides information for monitoring of mean inrcease such as ANSS, ATS, a matrix of transient probabilities, suitable control limits when the data are (zero inflated) Poisson/binomial distribution. Functions in the tools such as `getAve` and `getContl` can be easily applied to other count processes.

Also, tools might be extended to more complicated CUSUM control chart. We leave these issues as our perpetual work.

`getAve` *Compute ATSs and Other Informations on Attribute VSI CUSUM Chart*

Description

Computation of ANSSs, ATSs and other related informations on attribute VSI CUSUM control chart for mean increase based on the Markov chain approach.

Usage

```
getAve(refv, contl, c.zero = 0, warnl = 0, ds = 1, dl = NULL,
  di = NULL, process, maxndec = 7L, maxnumsubI = 6000L)
```

Arguments

`refv`	A reference value of CUSUM statistic.
`contl`	A control limit in CUSUM control scheme.
`c.zero`	An initial state of CUSUM statistic (default is 0).
`warnl`	A warning limit in VSI control scheme (default is 0).
`ds`	The shorter sampling interval in VSI CUSUM control scheme (default is 1).

dl	The longer sampling interval in VSI CUSUM control scheme.
di	The sampling interval at initial state in VSI CUSUM control scheme.
process	An object of function standing for pmf of count process of interest. See 'Details'.
maxndec	The maximum number of decimal places of refv ($\leq$ 7L).
maxnumsubI	The maximum number of sub-intervals in [100,6000] to be used in applying the Markov chain approach.

Details

For CUSUM control chart for detecting mean increase, the CUSUM statistic (C_t) are defined as following:

$$C_t = max(C_{t-1}, 0) + X_t - k, t = 1, 2, ...,$$

wherein X_t is a count process of interest, k is the reference value and C_0 is the initial state.

The argument process is an object of function such that for given integer-valued vector x, process(x) returns $P(X = x)$ where X is a random variable of interest.

If the number of sub-intervals for transient states of Markov chain is greater than maxnsubI, it will be set to be a suitable value being less than or equal maxnsubI.

For ANSS, it is the same as that psi.s + psi.l + 1.

For ATS, it is the same as that (psi.s * ds) + (psi.l * dl) + di.

Invalid arguments rise an error with a helpful message.

This function currently provides only the case for monitoring of mean increase. We leave other issues as our future work.

Value

A list including followings:

endpoints	Endpoints used for implementation of a matrix of transition probabilities.
numsubI	Number of sub-intervals used for implementation of a matrix of transition probabilities.
lensubI	Length of sub-intervals used for implementation of a matrix of transition probabilities.
Q	A matrix of transition probabilities for Markov chain approach.
I_minus_Q	Matrix (I - Q) where I is an identity matrix of the same size as the Q.
I_minus_Q_inv	Inverse matrix of (I - Q).
I_minus_Q_inv_1	Row sums of I_minus_Q_inv.
initpr	A matrix of initial probabilities for Markov chain approach.
ds	The shorter sampling interval in VSI CUSUM control scheme.
dl	The longer sampling interval in VSI CUSUM control scheme.
di	The sampling interval at initial state in VSI CUSUM control scheme.

psi.s	Long-run proportion of shorter sampling intervals except initial state. See details
psi.l	Long-run proportion of longer sampling intervals except initial state. See details
refv.act	A reference value of CUSUM statistic used actually for computation.
contl.act	A control limit in CUSUM control scheme used actually for computation.
warnl.act	A warning limit in VSI control scheme used actually for computation.
c.zero.act	An initial state of CUSUM statistic used actually for computation.
ANSS	The computed average number of samples to signal for FSI CUSUM chart.
ATS	The computed average time to signal for FSI CUSUM chart.

References

Reynolds et al. (1990). CUSUM Charts with Variable Sampling Intervals, *Technometrics*, 32(4), 371-384.

See Also

getContl, getAve_Poisson, getAve_binomial.

Examples

```
# Example 1: Poisson distribution
getAve(refv = 5, contl = 8, c.zero = 0, warnl = 1, ds = 0.1,
       dl = NULL, di = NULL, process = function(x) dpois(x, lambda = 4),
       maxndec = 7L, maxnumsubI = 500L)
```

---

getAve_binomial *Compute ATSs and Other Informations on (Zero-Inflated) Binomial CUSUM Chart*

Description

Computation of ANSSs, ATSs and other related informations on (zero-inflated) binomial CUSUM chart.

Usage

```
getAve_binom(size, prob, refv, contl, c.zero = 0, warnl = 0, ds = 1,
  dl = NULL, di = NULL, maxndec = 7L, maxnumsubI = 6000L)

getAve_zibinom(rho, size, prob, refv, contl, c.zero = 0, warnl = 0,
  ds = 1, dl = NULL, di = NULL, maxndec = 7L, maxnumsubI = 6000L)
```

Arguments

rho	A length-one numeric vector of zero-inflated parameter in [0,1).
size	A length-one non-negative integer-valued vector of number of trials.
prob	A length-one numeric vector of probability of success in [0,1].
refv	A reference value of CUSUM statistic.
contl	A control limit in CUSUM control scheme.
c.zero	An initial state of CUSUM statistic (default is 0).
warnl	A warning limit in VSI control scheme (default is 0).
ds	The shorter sampling interval in VSI CUSUM control scheme (default is 1).
dl	The longer sampling interval in VSI CUSUM control scheme.
di	The sampling interval at initial state in VSI CUSUM control scheme.
maxndec	The maximum number of decimal places of `refv` ($\leq$ 7L).
maxnumsubI	The maximum number of sub-intervals in [100,6000] to be used in applying the Markov chain approach.

Details

`getAve_binom` and `getAve_zibinom` are wrapper functions of `getAve` for (zero-inflated) binomial CUSUM chart.

Value

A list from `getAve`. See `getAve` for more information.

References

Rakitzis et al. (2016). CUSUM Control Charts for the Monitoring of Zero-inflated Binomial Processes, *Quality and Reliability Engineering International*, **32**, 465-483.

See Also

`getAve`, getAve_Poisson.

Examples

```
# Example 1: Reproduction of results from Rakitzis et al. (2016)
rho <- 0.9
size <- 100
prob0 <- 0.01
refv <- 0.26
contl <- 3.86
deltas <- seq(1, 2, 0.1)
ANSSs <- numeric(length(deltas))
for(i in seq(deltas)) {
  prob1 <- deltas[i] * prob0
  ANSSs[i] <- getAve_zibinom(rho = rho, size = size, prob = prob1,
                             refv = refv, contl = contl)$ANSS
```

```
}
names(ANSSs) <- deltas
ANSSs <- round(ANSSs, 2)
ANSSs

# Example 2: ANSS profiles (h in seq(10L))
rho <- 0.9
size <- 100
prob0 <- 0.01
refv <- 0.26
h <- seq(10L)
ANSSs <- numeric(10)
for(i in seq(ANSSs)) {
  ANSSs[i] <- getAve_zibinom(rho = rho, size = size, prob = prob0,
                             refv = refv, contl = h[i], ds = 1)$ANSS
}
ANSSs
```

`getAve_Poisson` *Compute ATSs and Other Informations on (Zero-Inflated) Poisson CUSUM Chart*

Description

Computation of ANSSs, ATSs and other related informations on (zero-inflated) Poisson CUSUM chart.

Usage

```
getAve_pois(lambda, refv, contl, c.zero = 0, warnl = 0, ds = 1,
  dl = NULL, di = NULL, maxndec = 7L, maxnumsubI = 6000L)

getAve_zipois(rho, lambda, refv, contl, c.zero = 0, warnl = 0, ds = 1,
  dl = NULL, di = NULL, maxndec = 7L, maxnumsubI = 6000L)
```

Arguments

`rho`	A length-one numeric vector of zero-inflated parameter in [0,1).
`lambda`	A length-one positive numeric vector of mean.
`refv`	A reference value of CUSUM statistic.
`contl`	A control limit in CUSUM control scheme.
`c.zero`	An initial state of CUSUM statistic (default is 0).
`warnl`	A warning limit in VSI control scheme (default is 0).
`ds`	The shorter sampling interval in VSI CUSUM control scheme (default is 1).
`dl`	The longer sampling interval in VSI CUSUM control scheme.

di	The sampling interval at initial state in VSI CUSUM control scheme.
maxndec	The maximum number of decimal places of refv ($\leq$ 7L).
maxnumsubI	The maximum number of sub-intervals in [100,6000] to be used in applying the Markov chain approach.

Details

getAve_pois and getAve_zipois are wrapper functions of getAve for (zero-inflated) Poisson CUSUM chart.

Value

A list from getAve. See getAve for more information.

References

White et al. (1997). POISSON CUSUM VERSUS c CHART FOR DEFECT DATA, *Quality Engineering*, **9**:4, 673-679.

See Also

getAve, getAve_binomial.

Examples

```
# Example 1: Reproduction of results from White et al. (1997)
tbl <- list()
arglist <- list(list(mu.a = 1, k = 2, h = 2),
                list(mu.a = 4, k = 5, h = 8),
                list(mu.a = 8, k = 10, h = 10),
                list(mu.a = 12, k = 15, h = 11))
deltas <- seq(0, 2.5, 0.5)
for(i in seq_along(arglist)) {
  argument <- arglist[[i]]
  arl <- numeric(length(deltas))
  for(j in seq_along(deltas)) {
    std.a <- sqrt(argument$mu.a)
    arl[j] <- getAve_pois(lambda = argument$mu.a + (std.a * deltas[j]),
                          refv = argument$k,
                          contl = argument$h)$ANSS
  }
  tbl[[i]] <- round(arl, 2)
}
tbl <- data.frame(tbl)
colnames(tbl) <- c("CUSUM(2,2)", "CUSUM(5,8)", "CUSUM(10,10)", "CUSUM(15,11)")
rownames(tbl) <- as.character(deltas)
cat("colnames stand for CUSUM(k,h)\n",
    "rownames stand for delta\n", sep = "")
tbl

# Example 2: ANSS profiles (h in seq(20L))
```

```
mu.a <-  4
k  <-  5
h <- seq(20)
ANSSs <- numeric(20)
for(i in seq(ANSSs)) {
  ANSSs[i] <- getAve_pois(lambda = mu.a, refv = k, contl = h[i], c.zero = 0,
                          warnl = 1, ds = 1)$ANSS
}
ANSSs
```

`getContl` *Compute Control Limits for Attribute FSI CUSUM Chart*

Description

Computation of suitable control limits for attribute FSI-CUSUM control chart for mean increase based on specified reference value and in-control ANSS/ARL.

Usage

```
getContl(anss.target = 370.4, refv, c.zero = 0, process, maxndec = 7L,
  maxnumsubI = 6000L)
```

Arguments

`anss.target`	A predetermined in-control ANSS/ARL ($\leq$50000L), default is 370.4.
`refv`	A reference value of CUSUM statistic.
`c.zero`	An initial state of CUSUM statistic (default is 0).
`process`	An object of function standing for pmf of count process of interest. See 'Details'.
`maxndec`	The maximum number of decimal places of `refv` ($\leq$ 7L).
`maxnumsubI`	The maximum number of sub-intervals in [100,6000] to be used in applying the Markov chain approach.

Details

For CUSUM control chart for detecting mean increase, the CUSUM statistic (C_t) are defined as following:

$$C_t = max(C_{t-1}, 0) + X_t - k, t = 1, 2, ...,$$

wherein X_t is a count process of interest, k is the reference value and C_0 is the initial state.

The argument `process` is an object of function such that for given integer-valued vector `x`, `process(x)` returns $P(X = x)$ where X is a random variable of interest.

If the number of sub-intervals for transient states of Markov chain is greater than `maxnsubI`, it will be set to be a suitable value being less than or equal `maxnsubI`.

Invalid arguments rise an error with a helpful message.

This function currently provides only the case for monitoring of mean increase. We leave other issues as our future work.

Value

A list including followings:

`refv.act`	A reference value of CUSUM statistic used actually for computation.
`c.zero.act`	An initial state of CUSUM statistic used actually for computation.
`sol1,sol2`	Vector of control limits and corresponding ANSS/ARLs

References

Reynolds et al. (1990). CUSUM Charts with Variable Sampling Intervals, *Technometrics*, 32(4), 371-384.

See Also

`getAve`.

Examples

```
# Example 1: Poisson distribution
getContl(anss.target = 200, refv = 5, c.zero = 0,
         process = function(x) dpois(x, lambda = 4))
```

`getContl_binomial` *Compute Control Limits for FSI binomial CUSUM Control Chart*

Description

Computation of suitable control limits for (zero-inflated) FSI binomial CUSUM control chart based on specified reference value and in-control ANSS/ARL.

Usage

```
getContl_binom(size, prob, anss.target = 370.4, refv, c.zero = 0,
  maxndec = 7L, maxnumsubI = 6000L)

getContl_zibinom(rho, size, prob, anss.target = 370.4, refv, c.zero = 0,
  maxndec = 7L, maxnumsubI = 6000L)
```

Arguments

rho	A length-one numeric vector of zero-inflated parameter in [0,1).
size	A length-one non-negative integer-valued vector of number of trials.
prob	A length-one numeric vector of probability of success in [0,1].
anss.target	A predetermined in-control ANSS/ARL ($\leq$50000L), default is 370.4.
refv	A reference value of CUSUM statistic.
c.zero	An initial state of CUSUM statistic (default is 0).
maxndec	The maximum number of decimal places of refv ($\leq$ 7L).
maxnumsubI	The maximum number of sub-intervals in [100,6000] to be used in applying the Markov chain approach.

Details

getContl_binom and getContl_zibinom are wrapper functions of getContl (zero-inflated) for binomial distribution.

Value

A list from getContl. See getContl for more information.

References

Rakitzis et al. (2016). CUSUM Control Charts for the Monitoring of Zero-inflated Binomial Processes, *Quality and Reliability Engineering International*, **32**, 465-483.

See Also

getContl, getContl_Poisson.

Examples

```
# Example 1: zero-inflated binomial distribution
getContl_zibinom(rho = 0.9, size = 100, prob = 0.01,
                 anss.target = 370.4, refv = 0.26, c.zero = 0)
```

---

getContl_Poisson *Compute Control Limits for FSI Poisson CUSUM Control Chart*

Description

Computation of suitable control limits for (zero-inflated) FSI Poisson CUSUM control chart based on specified reference value and in-control ANSS/ARL.

Usage

```
getContl_pois(lambda, anss.target = 370.4, refv, c.zero = 0, maxndec = 7L,
  maxnumsubI = 6000L)

getContl_zipois(rho, lambda, anss.target = 370.4, refv, c.zero = 0,
  maxndec = 7L, maxnumsubI = 6000L)
```

Arguments

rho	A length-one numeric vector of zero-inflated parameter in [0,1).
lambda	A length-one positive numeric vector of mean.
anss.target	A predetermined in-control ANSS/ARL ($\leq$50000L), default is 370.4.
refv	A reference value of CUSUM statistic.
c.zero	An initial state of CUSUM statistic (default is 0).
maxndec	The maximum number of decimal places of refv ($\leq$ 7L).
maxnumsubI	The maximum number of sub-intervals in [100,6000] to be used in applying the Markov chain approach.

Details

getContl_pois and getContl_zipois are wrapper functions of getContl for (zero-inflated) Poisson distribution.

Value

A list from getContl. See getContl for more information.

References

White et al. (1997). POISSON CUSUM VERSUS c CHART FOR DEFECT DATA, *Quality Engineering*, **9**:4, 673-679.

See Also

getContl, getContl_binomial.

Examples

```
# Example 1: Poisson distribution
getContl_pois(lambda = 4, anss.target = 200, refv = 5, c.zero = 0)
```

XtToCt *Convert from Data to FSI CUSUM Statistic*

Description

Conversion of data to FSI CUSUM statistic for monitoring of mean increase.

Usage

```
XtToCt(Xt, refv, c.zero = 0, maxndec = 7L)
```

Arguments

Xt	A non-negative integer-valued vector of count process of interest.
refv	A reference value of CUSUM statistic.
c.zero	An initial state of CUSUM statistic (default is 0).
maxndec	The maximum number of decimal places of refv ($\leq$ 7L).

Details

For CUSUM control chart for detecting mean increase, the CUSUM statistic (C_t) are defined as following:

$$C_t = max(C_{t-1}, 0) + X_t - refv, t = 1, 2, ...,$$

wherein X_t is a count process of interest.

Value

A time-series object of CUSUM statistic for monitoring of mean increase.

Examples

```
# Example 1: Poisson distribution
Ct <- XtToCt(Xt = rpois(200L, 4), refv = 5, c.zero = 0)
plot(Ct, type = "o", pch = 16, main = "CUSUM statistic",
     ylab = expression(C[t]),
     sub = expression(paste(C[t],"=", "max(",C[t - 1],",",0,")",
                            "+ refv -",X[t])))
```

zibinom *The Zero Inflated Binomial Distribution*

Description

Density, distribution function, quantile function and random generation for the zero inflated binomial distribution with parameters (rho, size, prob).

Usage

```
dzibinom(x, rho, size, prob, log = FALSE)

pzibinom(q, rho, size, prob, lower.tail = TRUE, log.p = FALSE)

qzibinom(p, rho, size, prob, lower.tail = TRUE, log.p = FALSE)

rzibinom(n, rho, size, prob)
```

Arguments

x	A non-negative integer-valued vector of quantiles.
q	A numeric vector of quantiles.
p	A vector of probabilities.
n	Number of random values to return, a length-one positive integer-valued vector.
rho	A length-one vector of zero inflation parameter on [0,1].
size	A length-one vector of number of trials (zero or more).
prob	A length-one vector of probability of success on each trial.
log, log.p	A length-one logical vector; if TRUE, probabilities p are given as log(p).
lower.tail	A length-one logical vector; if TRUE (the default), probabilities are $P(X \leq x)$, otherwise, $P(X > x)$.

Details

The probability mass function of X is given by

$$P(X = x) = rhoI(x = 0) + (1 - rho)P(Y = x), x = 0, 1, 2, ...,$$

where Y is distributed binomial(size, prob).

Value

`dzibinom` gives the (log) density, `pzibinom` gives the (log) distribution function, `qzibinom` gives the quantile function, and `rzibinom` generates random deviates.

Invalid arguments rise an error.

See Also

Binomial for the binomial distribution.

Examples

```
# Example 1: dzibinom
dzibinom(x = 0:10, rho = 0.1, size = 5, prob = 0.5)

# Example 2: pzibinom
pzibinom(q = 2, rho = 0.1, size = 5, prob = 0.5)

# Example 3: qzibinom
qzibinom(p = pzibinom(2, 0.1, 5, 0.5), rho = 0.1, size = 5, prob = 0.5)

# Example 4: rzibinom
n <- 1e+5
rho <- 0.2
size <- 5
prob <- 0.5
mean(rzibinom(n, rho, size, prob)) # Sample mean
(size * prob) * (1 - rho) # Theoretical mean
```

---

zipois *The Zero Inflated Poisson Distribution*

Description

Density, distribution function, quantile function and random generation for the zero inflated Poisson distribution with parameters (rho, lambda).

Usage

```
dzipois(x, rho, lambda, log = FALSE)

pzipois(q, rho, lambda, lower.tail = TRUE, log.p = FALSE)

qzipois(p, rho, lambda, lower.tail = TRUE, log.p = FALSE)

rzipois(n, rho, lambda)
```

Arguments

x	A non-negative integer-valued vector of quantiles.
q	A numeric vector of quantiles.
p	A vector of probabilities.
n	Number of random values to return, a length-one positive integer-valued vector.
rho	A length-one vector of zero inflation parameter on [0,1].

`lambda`	A length-one vector of positive means.
`log, log.p`	A length-one logical vector; if TRUE, probabilities p are given as log(p).
`lower.tail`	A length-one logical vector; if TRUE (the default), probabilities are $P(X \leq x)$, otherwise, $P(X > x)$.

Details

The probability mass function of X is given by

$$P(X = x) = rhoI(x = 0) + (1 - rho)P(Y = x), x = 0, 1, 2, ...,$$

where Y is distributed Poisson(lambda).

Value

`dzipois` gives the (log) density, `pzipois` gives the (log) distribution function, `qzipois` gives the quantile function, and `rzipois` generates random deviates.

Invalid arguments rise an error with a helpful message.

References

Lambert, D. (1992). Zero-Inflated Poisson Regression, with an Application to Defects in Manufacturing, *Technometrics*, **34**(1), 1-14.

See Also

Poisson for the Poisson distribution.

Examples

```
# Example 1: dzipois
dzipois(x = 0:10, rho = 0.1, lambda = 5)

# Example 2: pzipois
pzipois(q = 2, rho = 0.1, lambda = 5)

# Example 3: qzipois
qzipois(p = pzipois(2, 0.1, 5), rho = 0.1, lambda = 5)

# Example 4: rzipois
n <- 1e+5
rho <- 0.2
lambda <- 5
mean(rzipois(n, rho, lambda)) # Sample mean
lambda * (1 - rho) # Theoretical mean
```

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