Package 'crossrun'

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Version 0.1.1

Title Joint Distribution of Number of Crossings and Longest Run

Description Joint distribution of number of crossings and the longest run in a series of independent Bernoulli trials. The computations uses an iterative procedure where computations are based on results from shorter series. The procedure conditions on the start value and partitions by further conditioning on the position of the first crossing (or none).

Depends R (>= 3.5)

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URL https://github.com/ToreWentzel-Larsen/crossrun

Encoding UTF-8

LazyData true

Imports Rmpfr (>= 0.7-1)

RoxygenNote 7.1.2

Suggests knitr, rmarkdown

VignetteBuilder knitr

NeedsCompilation no

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Contents

`boxprobt` *Box Cumulative Sums*

Description

A box cumulative sum is defined as the cumulative sum over a lower left rectangle. This function is primarily for use when the components are point probabilities for the number of crossings C and the longest run L, then component (c,l) in the result is the probability $P(C \geq c, L \leq l)$.

Usage

```
boxprobt(mtrx)
```

Arguments

`mtrx`	mpfr array

Value

mpfr array

Examples

```
nill <- Rmpfr::mpfr(0, 120)
one <- Rmpfr::mpfr(1, 120)
two <- Rmpfr::mpfr(2, 120)
contents <- c(one,nill,nill, one,one,one, two,two,two)
mtrx3 <- Rmpfr::mpfr2array(contents, dim = c(3, 3))
print(mtrx3)
print(boxprobt(mtrx3))
```

---

clshift *Number of Crossings and Longest Run*

Description

Auxiliary function for simclbin, computing the number of crossings (type=0) or longest run (type=2) in a sequence of independent normal observations. Crossings and runs are related to whether the observations are above a shift.

Usage

```
clshift(seri, shift = 0, type = 0)
```

Arguments

seri	numeric; seri a sequence of random draws
shift	numeric; shift for the observatoobs
type	numeric; 0 number of crossings, 1 longest run

Value

number of crossings or longest run, numeric

---

crossrunauto *Joint Distribution for Crossings and Runs, autocorrelated Sequence*

Description

Joint probability distribution for the number of crossings C and the longest run L in a sequence of n autocorrelated Bernoulli observations with success probability p. To enhance precision, results are stored in mpfr arrays and the probabilities are multiplied by m^{n-1} for a multiplier m.

Usage

```
crossrunauto(
  nmax = 100,
  prob = 0.5,
  changeprob = 0.5,
  mult = 2,
  prec = 120,
  printn = FALSE
)
```

Arguments

nmax	max sequence length.
prob	success probability p.
changeprob	unrestricted change probability. If $p \geq 0.5$, probability of changing to success, if not probability of changing to failure.
mult	multiplier for joint probabilities.
prec	mpft precision.
printn	logical for progress output.

Value

list of joint probabilities.

Examples

```
# p=0.6, independence
cr10.6 <- crossrunbin(nmax=10, prob=0.6, printn=TRUE)
cra10.6 <- crossrunauto(nmax=10, prob=0.6, changeprob=.6, printn=TRUE)
Rmpfr::asNumeric(cr10.6$pt[[10]])
Rmpfr::asNumeric(cr10.6$pt[[10]])
Rmpfr::asNumeric(cr10.6$pt[[10]]) - Rmpfr::asNumeric(cra10.6$pt[[10]]) # equal


# p=0.6, some dependence
cr10.6 <- crossrunbin(nmax=10, prob=0.6, printn=TRUE)
cra10.6.u.5 <- crossrunauto(nmax=10, prob=0.6, changeprob=.5, printn=TRUE)
round(Rmpfr::asNumeric(cr10.6$pt[[10]]),1)
round(Rmpfr::asNumeric(cra10.6.u.5$pt[[10]]),1) # not the same
```

---

crossrunbin *Joint Distribution for Crossings and Runs*

Description

Joint probability distribution for the number of crossings C and the longest run L in a sequence of n independent Bernoulli observations with success probability p. To enhance precision, results are stored in mpfr arrays and the probabilities are multiplied by m^{n-1} for a multiplier m.

Usage

```
crossrunbin(nmax = 100, prob = 0.5, mult = 2, prec = 120, printn = FALSE)
```

Arguments

nmax	max sequence length.
prob	success probability.
mult	multiplier for joint probabilities.
prec	mpft precision.
printn	logical for progress output.

Value

list of joint probabilities.

Examples

```
crb10.6 <- crossrunbin(nmax=10, prob=.6, printn=TRUE)
print(crb10.6$pt[[10]])
```

---

crossrunchange *Joint Distribution for Crossings and Runs, Varying Success Probability.*

Description

Joint probability distribution for the number of crossings C and the longest run L in a sequence of n independent Bernoulli observations with p ossibly varying success probability. To enhance precision, results are stored in mpfr arrays and the probabilities are multiplied by m^{n-1} for a multiplier m.

Usage

```
crossrunchange(
  nmax = 100,
  prob = rep(0.5, 100),
  mult = 2,
  prec = 120,
  printn = FALSE
)
```

Arguments

nmax	max sequence length.
prob	success probabilities.
mult	multiplier for joint probabilities.
prec	mpft precision.
printn	logical for progress output.

Value

list pt of joint probabilities. Cumulative probabilities qt within each row are also included. Further, mostly for code checking, lists pat and qat conditional on starting with a success, and pbt and qbt conditional of starting with a failure, are included.

Examples

```
prob10 <- c(rep(.5,5),rep(.7,5))
crchange10 <- crossrunchange(nmax=10, prob=prob10,printn=TRUE)
print(crchange10$pt[[10]])
```

`crossrunem` *Joint Distribution for Crossings and Runs Using the Empirical Median.*

Description

Joint probability distribution for the number of crossings C and the longest run L in a sequence of n Bernoulli observations where the number of successes is fixed at m, m between 0 and n. For fixed n, the joint distribution is computed for all m, this makes the computation demanding in terms of time and storage requirements. The joint distribution is computed separately for sequences where the first observation is, or is not, a success. The results are mainly intended for use when n is even and m=n/2, but computation in this case requires that all distributions are computed previously for all m, for all shorter sequences (lower n). In the case of even n and m=n/2, the distributions for sequences starting or not with a success are identical, and only the distribution among sequences starting with a success is used. In that case, this may be interpreted as the joint distribution for sequences around the empirical median.

Usage

```
crossrunem(nmax = 100, prec = 120, printn = FALSE)
```

Arguments

`nmax`	max sequence length.
`prec`	mpft precision.
`printn`	logical for progress output.

Value

nfi, number of sequences with m successes, starting with a success, and nfn, number of sequences with m successes, not starting with a success. Three-dimensional Rmpfr arrays for each n up to nmax, with dimensions n (C=0 to n-1), n (L=1 to n) and n+1 (m=0 to n). For n even and m=n/2, only nfi, and the part corresponding to C=1 to n-1 and L=1 and m=n/2 is non-zero and should be used.

Examples

```
crem14 <- crossrunem(nmax=14, printn=TRUE)
Rmpfr::asNumeric(crem14$nfi[[14]][,,"m=7"]) # subsets of size 7=14/2
# restricted to possible values of C and L
Rmpfr::asNumeric(crem14$nfi[[14]][-1,1:7,"m=7"]) # same as stored data joint14em
Rmpfr::asNumeric(crem14$nfn[[14]][-1,1:7,"m=7"]) # the same

# subsets of sizes different from 14/2
# size 4, first observation included
Rmpfr::asNumeric(crem14$nfi[[14]][,,"m=4"])
# size 14-4=10, first observation not included
Rmpfr::asNumeric(crem14$nfn[[14]][,,"m=10"]) # the same
```

`crossrunemcont` *Continuation of an existing sequence of joint probabilities for crossings and longest run, based on the empirical median.*

Description

Continuation of an existing sequence of the number of crossings C and the longest run L in a sequence of n independent continuous observations classified as above or below the empirical median. To enhance precision, results are stored in mpfr arrays and the probabilities are multiplied by $choose(n, m)/2$ where m=n/2, even n assumed. The probabilities are integers in this representation.

Usage

```
crossrunemcont(emstart, n1 = 61, nmax = 100, prec = 120, printn = FALSE)
```

Arguments

`emstart`	existing sequence
`n1`	sequence length for the first new case addedc
`nmax`	max sequence length.
`prec`	mpft precision.
`printn`	logical for including progress output.

Value

nfi, number of sequences with m successes, starting with a success, and nfn, number of sequences with m successes, not starting with a success.

crossrunshift *wrapper for crossrunbin, success probability=pnorm(shift).*

Description

wrapper for crossrunbin, success probability=pnorm(shift).

Usage

```
crossrunshift(nmax = 100, shift = 0, mult = 2, prec = 120, printn = FALSE)
```

Arguments

nmax	max sequence length.
shift	mean of normal distribution.
mult	multiplier for joint probabilities.
prec	mpft precision.
printn	logical for progress output.

Value

list pt of joint probabilities. Cumulative probabilities qt within each row are also included. Further, mostly for code checking, lists pat and qat conditional on starting with a success, and pbt and qbt conditional of starting with a failure, are included.

Examples

```
crs15 <- crossrunshift(nmax=15,printn=TRUE)
print(crs15$pt[[15]])
```

crossrunsymm *Joint Probabilities for Crossings and Runs, Symmetric Case*

Description

Joint probability distribution for the number of crossings C and the longest run L in a sequence of n independent Bernoulli observations with success probability p. To enhance precision, results are stored in mpfr arrays and the probabilities are multiplied by m^{n-1} for a multiplier m. This is for the symmetric case with success probability 0.5, in which the multiplied probabilities are integers for the default value 2 of the multiplier.

Usage

```
crossrunsymm(nmax = 100, mult = 2, prec = 120, printn = FALSE)
```

Arguments

nmax	; max sequence length.
mult	; multiplier for joint probabilities. Default 2.
prec	; mpft precision.
printn	; logical for including progress output.

Value

pt, list of joint probabilities, multiplied with m^{n-1}. In addition cumulative probabilities qt within each row are also included.

Examples

```
crs10 <- crossrunsymm(nmax=10,printn=TRUE)
```

---

cumsumm *Row-wise Cumulative Sums*

Description

Row-wise Cumulative Sums in mpfr Array.

Usage

```
cumsumm(mtrx)
```

Arguments

mtrx	mpfr two-dimensional array.

Value

mpfr array with row-wise cumulative sums, same dimension as the original array.

Examples

```
nill <- Rmpfr::mpfr(0, 120)
one <- Rmpfr::mpfr(1, 120)
two <- Rmpfr::mpfr(2, 120)
contents <- c(one,nill,nill, one,one,one, two,two,two)
mtrx3 <- Rmpfr::mpfr2array(contents, dim = c(3, 3))
print(mtrx3)
print(cumsumm(mtrx3))
```

cumsummcol *Column-Wise Cumulative Sums*

Description

Column-wise cumulative sums in mpfr array.

Usage

```
cumsummcol(mtrx)
```

Arguments

mtrx	mpfr two-dimensional array.

Value

mpfr array with column-wise cumulative sums, same dimension as the original array.

Examples

```
nill <- Rmpfr::mpfr(0, 120)
one <- Rmpfr::mpfr(1, 120)
two <- Rmpfr::mpfr(2, 120)
contents <- c(one,nill,nill, one,one,one, two,two,two)
mtrx3 <- Rmpfr::mpfr2array(contents, dim = c(3, 3))
print(mtrx3)
print(cumsummcol(mtrx3))
```

exactbin *Exact Joint Probabilities for Low n*

Description

Exact joint probabilities, for low n, of the number of crossings C and the longest run L in n independent Bernoulli observations with success probability p. Probabilites are multiplied by 2^{n-1}.

Usage

```
exactbin(n, p = 0.5, prec = 120)
```

Arguments

n	number, length of seqience, at most 6.
p	success probability.
prec	precision in mpfr calculations. Default 120.

Value

mpfr array

Examples

```
exactbin(n=6)
exactbin(n=5, p=0.6)
```

---

joint100.6 *Joint probabilities, n=100, success probability 0.6*

Description

The joint probabilities of the number C og crossings (0, ... 99) and the longest run L (1, ..., 100) in a series of n=100 independent Bernoulli observations for success probability 0.6. The probabilities are stored in the "times" representations, multiplied by 2^{100-1}. Only the joint distributions for n=15, 60, 100 and success probabilities 0.5 and 0.6 are included in the package to avoid excessive storage, but many more cases may be generated by the function crossrunbin.

Usage

```
joint100.6
```

Format

matrix, 100 rows and 100 columns

Source

generated by the function crossrunbin and transformed from an Rmpfr array to a matrix

---

joint100symm *Joint probabilities, n=100, symmetric case*

Description

The joint probabilities of the number C og crossings (0, ... 99) and the longest run L (1, ..., 100) in a series of n=100 independent Bernoulli observations for the symmetric case (success probability 0.5). The probabilities are stored in the "times" representations, multiplied by 2^{100-1} and are integers in the symmetric case. Only the joint distributions for n=15, 60, 100 and success probabilities 0.5 and 0.6 are included in the package to avoid excessive storage, but many more cases may be generated by the function crossrunsymm.

Usage

```
joint100symm
```

Format

matrix, 100 rows and 100 columns

Source

generated by the function crossrunsymm and transformed from an Rmpfr array to a matrix

---

joint14.6 *Joint probabilities, n=14, success probability 0.6*

Description

The joint probabilities of the number C og crossings (0, ... 13) and the longest run L (1, ..., 14) in a series of n=14 independent Bernoulli observations for success probability 0.6. The probabilities are stored in the "times" representations, multiplied by $2^{14-1} = 8192$. Only the joint distributions for n=14, 60, 100 and success probabilities 0.5 and 0.6 are included in the package to avoid excessive storage, but many more cases may be generated by the function crossrunbin.

Usage

```
joint14.6
```

Format

matrix, 14 rows and 14 columns

Source

generated by the function crossrunbin and transformed from an Rmpfr array to a matrix

---

joint14em *Joint probabilities, n=14, around the empirical median*

Description

Joint probabilities of the number C of crossings (1, ... 13) and the longest run L (1, ..., 17) in a series of n=60 Bernoulli observations around its empirical median. The probabilities are stored in the "times" representations, multiplied by (60 by 30)/2, the number of constellations starting above the median, and are integers. About the empirical median there is at least one crossing, and the longest run cannot exceed 14/2=7. Only the joint distributions for n=14, 60 are included in the package to avoid excessive storage, but many more cases may be generated by the function 'crossrunem. Since these computations are demanding in terms of storage and computation time, they are at present not performed for n much above 60.

Usage

```
joint14em
```

Format

matrix, 13 rows and 7 columns

Source

generated by the function crossrunsymm and transformed from an Rmpfr array to a matrix

---

`joint14symm` *Joint probabilities, n=14, symmetric case*

Description

Joint probabilities of the number C of crossings (0, ... 13) and the longest run L (1, ..., 14) in a series of n=14 independent Bernoulli observations for the symmetric case (success probability 0.5). The probabilities are stored in the "times" representations, multiplied by $2^{14-1} = 8192$ and are integers in the symmetric case. Only the joint distributions for n=14, 60, 100 and success probabilities 0.5 and 0.6 are included in the package to avoid excessive storage, but many more cases may be generated by the function crossrunsymm.

Usage

```
joint14symm
```

Format

matrix, 14 rows and 14 columns

Source

generated by the function crossrunsymm and transformed from an Rmpfr array to a matrix

joint60.6 *Joint probabilities, 60, success probability 0.6*

Description

The joint probabilities of the number C og crossings (0, ... 59) and the longest run L (1, ..., 60) in a series of n=60 independent Bernoulli observations for success probability 0.6. The probabilities are stored in the "times" representations, multiplied by 2^{60-1}. Only the joint distributions for n=15, 60, 100 and success probabilities 0.5 and 0.6 are included in the package to avoid excessive storage, but many more cases are generated in the script crossrun1.R.

Usage

```
joint60.6
```

Format

matrix, 60 rows and 60 columns

Source

generated by the function crossrunbin and transformed from an Rmpfr array to a matrix

joint60em *Joint probabilities, n=60, around the empirical median*

Description

Joint probabilities of the number C of crossings (1, ... 59) and the longest run L (1, ..., 30) in a series of n=14 Bernoulli observations around its empirical median. The probabilities are stored in the "times" representations, multiplied by (14 by 7)/2=1716, the number of constellations starting above the median, and are integers. About the empirical median there is at least one crossing, and the longest runcannot exceed 60/2=30. Only the joint distributions for n=14, 60 are included in the package to avoid excessive storage, but many more cases may be generated by the function 'crossrunem. Since these computations are demanding in terms of storage and computation time, they are at present not performed for n much above 60. '#'

Usage

```
joint60em
```

Format

matrix, 59 rows and 30 columns

Source

generated by the function crossrunem and transformed from an Rmpfr array to a matrix

joint60symm *Joint probabilities, n=60, symmetric case*

Description

The joint probabilities of the number C og crossings (0, ... 59) and the longest run L (1, ..., 60) in a series of n=60 independent Bernoulli observations for the symmetric case (success probability 0.5). The probabilities are stored in the "times" representations, multiplied by 2^{60-1} and are integers in the symmetric case. Only the joint distributions for n=15, 60, 100 and success probabilities 0.5 and 0.6 are included in the package to avoid excessive storage, but many more cases may be generated by the function crossrunsymm.

Usage

```
joint60symm
```

Format

matrix, 60 rows and 60 columns

Source

generated by the function crossrunsymm and transformed from an Rmpfr array to a matrix

simclbin *Simulation of Independent Bernoulli Observations*

Description

Simulation of a sequence of independent Bernoulli Observations. To reduce the amount of random draws, each simulation is based on a sequence of standard normal variables, and whether each observation is above a shift defined by the binomial probabilities assumed.

Usage

```
simclbin(nser = 100, nsim = 1e+05, probs = c(0.5, 0.6, 0.7, 0.8, 0.9))
```

Arguments

nser	length of sequence simulated
nsim	number of simulations
probs	binomial probabilites

Value

a data frame with the number of crossings and longest run for each probability. For instance the variables nc0.5 and lr0.5 are the number of crossings and the longest run for success probability 0.5. One row for each simulation.

Examples

```
cl30simbin <- simclbin(nser=30, nsim=100)
mean(cl30simbin$nc0.5) # mean number of crossings, p=0.5
mean(cl30simbin$lr0.9) # mean longest run, p=0.9
```

---

simclem *Check of joint probabilities by simulations*

Description

Simulation of a sequence of n=2m observations around the median in the sequence. To be used for checking the results of crossrunem.

Usage

```
simclem(m1 = 7, nsim = 1e+05)
```

Arguments

m1	half the sequence length
nsim	number of simulations

Value

data frame with cs, number of crossings and ls, longest run in the simulations.

Examples

```
simclem14 <- simclem(nsim=sum(joint14em))
print(table(simclem14)) # joint distributions in the simulations
print(joint14em) # for comparison
```

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