Package 'microsimulation'

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Type Package

Title Discrete Event Simulation in R and C++, with Tools for Cost-Effectiveness Analysis

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Description Discrete event simulation using both R and C++ (Karlsson et al 2016; <doi:10.1109/eScience.2016.7870915>). The C++ code is adapted from the SSIM library <https://www.inf.usi.ch/carzaniga/ssim/>, allowing for both event-oriented and process-oriented simulation. The code includes a SummaryReport class for reporting events and costs by age and other covariates. The C++ code is available as a static library for linking to other packages. A priority queue implementation is given in C++ together with an S3 closure and a reference class implementation. Finally, some tools are provided for cost-effectiveness analysis.

License GPL (>= 3)

Depends Rcpp (>= 0.10.2), methods

Imports parallel, grDevices, ascii

Suggests testthat

LinkingTo Rcpp, BH

LazyData true

URL https://github.com/mclements/microsimulation

BugReports https://github.com/mclements/microsimulation/issues

Encoding UTF-8

RoxygenNote 7.1.1

NeedsCompilation yes

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R topics documented:

`microsimulation-package`
microsimulation

Description

Discrete event simulations in both R and C++ with Tools for Cost-Effectiveness Analysis.

Introduction

Discrete event simulations in both R and C++ with Tools for Cost-Effectiveness Analysis.

Author(s)

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References

https://github.com/mclements/microsimulation

See Also

Rcpp

`.microsimulationLdFlags` *Internal function*

Description

Is this function needed? We could define the current stream in open code.

Again, is this needed?

Usage

```
.microsimulationLdFlags()

inlineCxxPlugin(...)

LdFlags()

microsimulation.init(PACKAGE = "microsimulation")

microsimulation.exit(PACKAGE = "microsimulation")

unsigned(seed)

signed(seed)

rnormPos(n, mean = 0, sd = 1, lbound = 0)

set.user.Random.seed(seed, PACKAGE = "microsimulation")

advance.substream(seed, n, PACKAGE = "microsimulation")

next.user.Random.substream(PACKAGE = "microsimulation")

user.Random.seed(PACKAGE = "microsimulation")

enum(obj, labels, start = 0)

enum(obj) <- value

RNGstate()

frontier(x, y, concave = TRUE, convex = NULL)

lines_frontier(x, y, pch = 19, type = "b", ...)

discountedPoint(y, time, dr)
```

```
ICER(object1, object2, ...)

.onLoad(lib, pkg)

.onUnload(libpath)
```

Arguments

...	other arguments
PACKAGE	package for the seed
seed	random number seed
n	number of sub-streams to advance
mean	numeric for the mean of the (untruncated) normal distribution (default=0)
sd	numeric for the sd of the (untruncated) normal distribution (default=1)
lbound	numeric for the lower bound (default=0)
obj	integer or logical for factor levels
labels	labels for the factor levels
start	first value of the levels
value	labels for the factor levels
x	vector of x coordinates
y	the undiscounted value
concave	logical for whether to calculate a concave frontier (default=TRUE)
convex	logical for whether to calculate a convex frontier (default=NULL)
pch	type of pch for the plotted symbols (default=19)
type	join type (default="b")
time	the time of the event
dr	discount rate, expressed as a percentage
object1	first object
object2	second object
lib	library string
pkg	package string
libpath	library path string

Value

No return value, called for side effects

No return value, called for side effects

No return value, called for side effects

unsigned seed

signed seed

numeric vector

invisibly returns the new seed

the advanced seed

invisibly returns TRUE – called for side effect

random seed

the new factor

update the factor

a list with oldseed (the old value of .Random.seed), and reset(), which resets .Random.seed

a list with components x and y for the frontier

No return value, called for side effects

numeric vector

`callCalibrationPerson` *call CalibrationPerson example*

Description

Example that uses the RngStream random number generator

Example that uses the Mersenne-Twister random number generator

Example that uses the Mersenne-Twister random number generator

Example that uses the Mersenne-Twister random number generator

Usage

```
callCalibrationPerson(
  seed = 12345,
  n = 500,
  runpar = c(4, 0.5, 0.05, 10, 3, 0.5),
  mc.cores = 1
)

callPersonSimulation(n = 20, seed = rep(12345, 6))

callSimplePerson(n = 10)

callSimplePerson2(n = 10)

callIllnessDeath(n = 10L, cure = 0.1, zsd = 0)
```

Arguments

seed	random number seed
n	number of simulations (default=10)
runpar	parameters
mc.cores	number of cores
cure	probability of cure
zsd	frailty standard deviation

Value

data-frame

data-frame

data-frame

data-frame

data-frame

---

discountedInterval *Integrate a discounted value*

Description

Integrate a discounted value

Usage

```
discountedInterval(y, start, finish, dr)
```

Arguments

y	the undiscounted value
start	the start time
finish	the finish time
dr	discount rate, expressed as a percentage

Value

numeric discounted value

fhcrcData *Old data used in the prostata model*

Description

Old data used in the prostata model

Usage

```
fhcrcData
```

Format

An object of class `list` of length 10.

pqueue *S3 priority queue implementation using C++*

Description

This provides a priority queue that is sorted by the priority and entry order. The priority is assumed to be numeric. The events can be of any type. As an extension, events can be cancelled if they satisfy a certain predicate. Note that the inactive events are not removed, rather they are marked as cancelled and will not be available to be popped.

Based on C++ code. See also the S3 implementation `pqueue`.

This event queue is simple and useful for pedagogic purposes.

Inherit from this class to represent a discrete event simulation. The API is similar to that for Omnet++, where an `init` method sets up the initial events using the `scheduleAt(time,event)` method, the messages are handled using the `handleMessage(event)` method, the simulation is run using the `run` method, and the `final` method is called at the end of the simulation.

Usage

```
pqueue(lower = TRUE)
```

Arguments

`lower`	boolean to determine whether to give priority to lower values (default=TRUE) or higher values

Details

The algorithm for pushing values into the queue is computationally very simple: simply rank the times using `order()` and re-order times and events. This approach is probably of acceptable performance for smaller queue. A more computationally efficient approach for pushing into larger queues would be to use a binary search (e.g. using `findInterval()`).

For faster alternatives, see `pqueue` and `PQueueRef`.

Value

a list with

push function with arguments priority (numeric) and event (SEXP). Pushes an event with a given priority

pop function to return a list with a priority (numeric) and an event (SEXP). This pops the first active event.

cancel function that takes a predicate (or R function) for a given event and returns a logical that indicates whether to cancel that event or not. This may cancel some events that will no longer be popped.

empty function that returns whether the priority queue is empty (or has no active events).

clear function to clear the priority queue.

ptr XPtr value

Fields

`ptr` External pointer to the C++ class

`times` vector of times

`events` list of events

`times` vector of times

`events` list of events

Methods

`cancel(predicate)` Method to cancel events that satisfy some predicate

`clear()` Method to clear the event queue

`empty()` Method to check whether there are no events in the queue

`initialize(lower = TRUE)` Method to initialize the object. lower argument indicates whether lowest priority or highest priority

`pop()` Method to remove the head of the event queue and return its value

`push(priority, event)` Method to push an event with a given priority

`cancel(predicate, ...)` Method to remove events that satisfy some predicate

`clear()` Method to clear the event queue

`empty()` Method to check whether there are no events in the queue

`pop()` Method to remove the head of the event queue and return its value

`push(time, event)` Method to insert the event at the given time

`final()` Method for finalising the simulation

`handleMessage(event)` Virtual method to handle the messages as they arrive

`init()` Virtual method to initialise the event queue and attributes

`reset(startTime = 0)` Method to reset the event queue

`run(startTime = 0)` Method to run the simulation

`scheduleAt(time, event)` Method that adds attributes for the event time and the sendingTime, and then insert the event into the event queue

Examples

```
pq = pqueue()
pq$push(3,"Clear drains")
pq$push(4, "Feed cat")
pq$push(5, "Make tea")
pq$push(1, "Solve RC tasks")
pq$push(2, "Tax return")
while(!pq$empty())
  print(pq$pop())

pq = new("PQueueRef")
pq$push(3,"Clear drains")
pq$push(4, "Feed cat")
pq$push(5, "Make tea")
pq$push(1, "Solve RC tasks")
pq$push(2, "Tax return")
while(!pq$empty())
  print(pq$pop())

pq = new("EventQueue")
pq$push(3,"Clear drains")
pq$push(4, "Feed cat")
pq$push(5, "Make tea")
pq$push(1, "Solve RC tasks")
pq$push(2, "Tax return")
while(!pq$empty())
  print(pq$pop())

DES = setRefClass("DES",
                  contains = "BaseDiscreteEventSimulation",
                  methods=list(
                      init=function() {
                         scheduleAt(3,"Clear drains")
                         scheduleAt(4, "Feed cat")
                         scheduleAt(5, "Make tea")
                         scheduleAt(1, "Solve RC tasks")
                         scheduleAt(2, "Tax return")
                      },
                      handleMessage=function(event) print(event)))

des = new("DES")
des$run()
## Not run:
testRsimulation1 <- function() {
    ## A simple example
    Simulation <-
        setRefClass("Simulation",
                    contains = "BaseDiscreteEventSimulation")
    Simulation$methods(
        init = function() {
            scheduleAt(rweibull(1,8,85), "Death due to other causes")
            scheduleAt(rweibull(1,3,90), "Cancer diagnosis")
```

```
        },
        handleMessage = function(event) {
            if (event %in% c("Death due to other causes", "Cancer death")) {
                clear()
                print(event)
            }
            else if (event == "Cancer diagnosis") {
                if (runif(1) < 0.5)
                    scheduleAt(now() + rweibull(1,2,10), "Cancer death")
                print(event)
            }
        })
    Simulation$new()$run()
}

## An extension with individual life histories
testRsimulation2 <- function(n=100) {
    Simulation <-
        setRefClass("Simulation",
                    contains = "BaseDiscreteEventSimulation",
                    fields = list(state = "character", report = "data.frame"))
    Simulation$methods(
        init = function() {
            report <<- data.frame()
            state <<- "Healthy"
            scheduleAt(rweibull(1,8,85), "Death due to other causes")
            scheduleAt(rweibull(1,3,90), "Cancer diagnosis")
        },
        handleMessage = function(event) {
            report <<- rbind(report, data.frame(state = state,
                                                begin = attr(event,"sendingTime"),
                                                end = currentTime,
                                                event = event,
                                                stringsAsFactors = FALSE))
            if (event %in% c("Death due to other causes", "Cancer death")) {
                clear()
            }
            else if (event == "Cancer diagnosis") {
                state <<- "Cancer"
                if (runif(1) < 0.5)
                    scheduleAt(now() + rweibull(1,2,10), "Cancer death")
            }
        },
        final = function() report)
    sim <- Simulation$new()
    do.call("rbind", lapply(1:n, function(id) data.frame(id=id,sim$run())))
}

## reversible illness-death model
testRsimulation3 <- function(n=100) {
    Simulation <-
        setRefClass("Simulation",
                    contains = "BaseDiscreteEventSimulation",
```

```
                    fields = list(state = "character", everCancer = "logical",
                                  report = "data.frame"))
    Simulation$methods(
        init = function() {
            report <<- data.frame()
            state <<- "Healthy"
            everCancer <<- FALSE
            scheduleAt(rweibull(1,8,85), "Death due to other causes")
            scheduleAt(rweibull(1,3,90), "Cancer diagnosis")
        },
        handleMessage = function(event) {
            report <<- rbind(report, data.frame(state = state,
                                                everCancer = everCancer,
                                                begin = attr(event,"sendingTime"),
                                                end = currentTime,
                                                event = event,
                                                stringsAsFactors = FALSE))
            if (event %in% c("Death due to other causes", "Cancer death")) {
                clear()
            }
            else if (event == "Cancer diagnosis") {
                state <<- "Cancer"
                everCancer <<- TRUE
                if (runif(1) < 0.5)
                    scheduleAt(now() + rweibull(1,2,10), "Cancer death")
                scheduleAt(now() + 10, "Recovery")
            }
            else if (event == "Recovery") {
                state <<- "Healthy"
                scheduleAt(now() + rexp(1,10), "Cancer diagnosis")
            }
        },
        final = function() report)
    sim <- Simulation$new()
    do.call("rbind", lapply(1:n, function(id) data.frame(id=id,sim$run())))
}

## cancer screening
testRsimulation4 <- function(n=1) {
    Simulation <-
        setRefClass("Simulation",
                    contains = "BaseDiscreteEventSimulation",
                    fields = list(state = "character", report = "data.frame"))
    Simulation$methods(
        init = function() {
            report <<- data.frame()
            state <<- "Healthy"
            scheduleAt(rweibull(1,8,85), "Death due to other causes")
            scheduleAt(rweibull(1,3,90), "Cancer onset")
            scheduleAt(50,"Screening")
        },
        handleMessage = function(event) {
            report <<- rbind(report, data.frame(state = state,
```

```
                                            begin = attr(event,"sendingTime"),
                                            end = currentTime,
                                            event = event,
                                            stringsAsFactors = FALSE))
            if (event %in% c("Death due to other causes", "Cancer death")) {
                clear()
            }
            else if (event == "Cancer onset") {
                state <<- event
                dx <- now() + rweibull(1,2,10)
                scheduleAt(dx, "Clinical cancer diagnosis")
                scheduleAt(dx + rweibull(1,1,10), "Cancer death")
                scheduleAt(now() + rweibull(1,1,10), "Metastatic cancer")
            }
            else if (event == "Metastatic cancer") {
                state <<- event
                cancel(function(event) event %in%
                       c("Clinical cancer diagnosis","Cancer death")) # competing events
                scheduleAt(now() + rweibull(1,2,5), "Cancer death")
            }
            else if (event == "Clinical cancer diagnosis") {
                state <<- event
                cancel(function(event) event == "Metastatic cancer")
            }
            else if (event == "Screening") {
                switch(state,
                       "Cancer onset" = {
                           state <<- "Screen-detected cancer diagnosis"
                           cancel(function(event) event %in%
                                  c("Clinical cancer diagnosis","Metastatic cancer"))
                       },
                       "Metastatic cancer" = {}, # ignore
                       "Clincal cancer diagnosis" = {}, # ignore
                       "Healthy" = {
                           if (now()<=68) scheduleAt(now()+2, "Screening")
                       })
            }
            else stop(event)
        },
        final = function() report)
    sim <- Simulation$new()
    do.call("rbind", lapply(1:n, function(id) data.frame(id=id,sim$run())))
}

## ticking bomb - toy example
testRsimulation5 <- function(n=1) {
    Simulation <-
        setRefClass("Simulation",
                    contains = "BaseDiscreteEventSimulation",
                    fields = list(report = "data.frame"))
    Simulation$methods(
        init = function() {
            report <<- data.frame()
```

```
            scheduleAt(rexp(1,1), "tick")
            if (runif(1)<0.1)
                scheduleAt(rexp(1,1), "explosion")
        },
        handleMessage = function(event) {
            report <<- rbind(report, data.frame(begin = attr(event,"sendingTime"),
                                                end = currentTime,
                                                event = event,
                                                stringsAsFactors = FALSE))
            if (event == "explosion")
                clear()
            else {
                clear() # queue
                if (event == "tick") scheduleAt(currentTime+rexp(1,1), "tock")
                else scheduleAt(currentTime+rexp(1,1), "tick")
                if (runif(1)<0.1)
                    scheduleAt(currentTime+rexp(1,1), "explosion")
            }
        },
        final = function() report)
    sim <- Simulation$new()
    do.call("rbind", lapply(1:n, function(id) data.frame(id=id,sim$run())))
}

## End(Not run)
```

---

pqueue__new *C++ function*

Description

C++ function

C++ function

C++ function

C++ function

C++ function

C++ function

C++ function

C++ function

C++ function

C++ function

C++ function

C++ function

Value

data-frame

No return value, called for side effects

No return value, called for side effects

No return value, called for side effects

No return value, called for side effects

No return value, called for side effects

No return value, called for side effects

`RNGStream` *S3 class to work with RngStream objects*

Description

S3 class to work with RngStream objects

Use RNGStream as an old class

With method for RNGStream S3 class

Usage

```
RNGStream(nextStream = TRUE, iseed = NULL)

## S3 method for class 'RNGStream'
with(data, expr, ...)
```

Arguments

`nextStream`	whether to move to the next stream (default=TRUE)
`iseed`	set seed after changing RNG (otherwise keep the current seed)
`data`	object of type RNGStream
`expr`	expression using the RNGStream
`...`	other arguments passed to eval()

Value

list of class `RNGStream` with components:

resetRNGkind function to reset to the previous RNG and seed

seed function to return the current seed itemopenfunction to use the current seed itemclosefunction to make the current seed equal to .Random.seed itemresetStreamfunction to move back to start of stream itemresetSubStreamfunction to move back to start of sub-stream itemnextSubStreamfunction to move to next sub-stream itemnextStreamfunction to move to next stream

the value from the expression

Examples

```
## set up one stream
s1 <- RNGStream()
s1$open()
rnorm(1)
s1$nextSubStream()
rnorm(1)
## reset the stream
s1$resetStream()
rnorm(2)
s1$nextSubStream()
rnorm(2)

## now do with two streams
s1$resetStream()
s2 <- RNGStream()
with(s1,rnorm(1))
with(s2,rnorm(1))
s1$nextSubStream()
with(s1,rnorm(1))
## now reset the streams and take two samples each time
s1$resetStream()
s2$resetStream()
with(s1,rnorm(2))
with(s2,rnorm(2))
s1$nextSubStream()
with(s1,rnorm(2))
```

---

summary.SummaryReport *summary method for a SummaryReport object*

Description

At present, this passes the object to summary and then prints

Usage

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

## S3 method for class 'summary.SummaryReport'
print(x, ...)

## S3 method for class 'SummaryReport'
print(x, ...)

## S3 method for class 'SummaryReport'
rbind(...)
```

```
## S3 method for class 'SummaryReport'
ascii(
  object,
  include.rownames = FALSE,
  include.colnames = TRUE,
  header = TRUE,
  digits = c(0, 3, 2, 2, 4, 4),
  ...
)

## S3 method for class 'SummaryReport'
ICER(object1, object2, ...)

## S3 method for class 'ICER.SummaryReport'
ascii(
  object,
  include.rownames = TRUE,
  include.colnames = TRUE,
  header = TRUE,
  digits = c(1, 1, 3, 3, 1, 1, 3, 3, 1),
  rownames = c("Reference", "Treatment"),
  colnames = c("Costs", "(se)", "QALYs", "(se)", "Costs", "(se)", "QALYs", "(se)",
    "ICER"),
  tgroup = c("Total", "Incremental"),
  n.tgroup = c(4, 5),
  ...
)
```

Arguments

object	an ICER.SummaryReport object
...	other arguments to pass to ascii
x	SummaryReport object
include.rownames	logical for whether to include rownames (default=FALSE)
include.colnames	logical for whether to include colnames (default=TRUE)
header	logical for whether to include the header (default=TRUE)
digits	vector of the number of digits to use for each column
object1	SummaryReport object (reference)
object2	SummaryReport object
rownames	rownames for output
colnames	colnames for output
tgroup	tgroup arg passed to ascii
n.tgroup	arg passed to ascii

Value

a list of class summary.SummaryReport with components:

n Number of simulations

indivip boolean with whether individual values were retained

utilityDiscountRate discount rate for utilities/QALYs

costDiscountRate discount rate for costs

QALE Quality-adjusted life expectancy (discounted)

LE Life expectancy (not discounted)

ECosts Life-time expected costs (discounted)

se.QALE standard error for QALE

se.Ecosts standard error Ecosts

a SummaryReport object

ascii object

a list of type ICER.SummaryReport with components:

n number of simulations

utilityDiscountRate Discount rate for the utilities/QALE

costDiscountRate Discount rate for the costs

s1 summary for object1

s2 summary for object2

dQALE QALE for object2 minus QALE for object1

dCosts Costs for object2 minus costs for object1

ICER change of costs divided by change in QALEs

se.dQALE standard error for dQALE

se.dCosts standard error for dCosts

ascii object

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