

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++ (Karls-
son et al 2016; <[doi:10.1109/eScience.2016.7870915](https://doi.org/10.1109/eScience.2016.7870915)>). The C++ code is adapted from the SSIM li-
brary <<https://www.inf.usi.ch/carzaniga/ssim/>>, allowing for event-oriented simula-
tion. The code includes a SummaryReport class for reporting events and costs by age and other co-
variates. The C++ code is available as a static library for linking to other packages. A prior-
ity queue implementation is given in C++ together with an S3 closure and a reference class im-
plementation. Finally, some tools are provided for cost-effectiveness analysis.

License GPL (>= 3)

Depends Rcpp (>= 0.10.2), methods

Imports parallel, grDevices, ascii, survival

Suggests testthat

LinkingTo Rcpp, RcppArmadillo

LazyData true

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

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

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NeedsCompilation yes

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microsimulation-package
<i>microsimulation</i>

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)

Mark Clements <mark.clements@ki.se>

References

<https://github.com/mclements/microsimulation>

See Also

[sourceCpp](#)

`.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	<i>Integrate a discounted value</i>
--------------------	-------------------------------------

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	<i>Old data used in the prostata model</i>
-----------	--

Description

Old data used in the prostata model

Usage

fhcrcData

Format

An object of class list of length 10.

pqueue	<i>S3 priority queue implementation using C++</i>
--------	---

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
    "Clinical 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	<i>C++ function</i>
-------------	---------------------

Description

[illegible]

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	<i>S3 class to work with RngStream objects</i>
-----------	--

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
- open** function to use the current seed
- close** function to make the current seed equal to .Random.seed
- resetStream** function to move back to start of stream

resetSubStream function to move back to start of sub-stream

nextSubStream function to move to next sub-stream

nextStream function 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))
```

simulate.survreg	<i>Simulate event times from a survreg object</i>
------------------	---

Description

Simulate event times from a survreg object

Usage

```
## S3 method for class 'survreg'
simulate(object, nsim = 1, seed = NULL, newdata, t0 = NULL, ...)
```

Arguments

object	survreg object
nsim	number of simulations per row in newdata
seed	random number seed
newdata	data-frame for defining the covariates for the simulations. Required.
t0	delayed entry time. Defaults to NULL (which assumes that t0=0)
...	other arguments (not currently used)

Value

vector of event times with nsim repeats per row in newdata

Examples

```
library(survival)
fit <- survreg(Surv(time, status) ~ ph.ecog + age + sex + strata(sex),
               data = lung)
nd = transform(expand.grid(ph.ecog=0:1, sex=1:2), age=60)
simulate(fit, seed=1002, newdata=nd)
simulate(fit, seed=1002, newdata=nd, t0=500)
```

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(
  x,
  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(
  x,
  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	SummaryReport object
...	other arguments to pass to ascii
x	an ICER.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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