Package 'IBMPopSim'

February 9, 2024

Type Package

Title Individual Based Model Population Simulation

Version 1.0.0

Date 2024-02-06

Maintainer Daphné Giorgi <daphne.giorgi@sorbonne-universite.fr>

Description

Simulation of the random evolution of heterogeneous populations using stochastic Individual-Based Models (IBMs) <doi:10.48550/arXiv.2303.06183>.
The package enables users to simulate population evolution, in which individuals are characterized by their age and some characteristics, and the population is modified by different types of events, including births/arrivals, death/exit events, or changes of characteristics. The frequency at which an event can occur to an individual can depend on their age and characteristics, but also on the characteristics of other individuals (interactions).
Such models have a wide range of applications. For instance, IBMs can be used for simulating the evolution of a heterogeneous insurance portfolio with selection or for validating mortality forecasts.
This package overcomes the limitations of time-consuming IBMs simulations by implementing new efficient algorithms based on thinning methods, which are compiled using the 'Rcpp' package while providing a user-friendly interface.

URL https://github.com/DaphneGiorgi/IBMPopSim, https://DaphneGiorgi.github.io/IBMPopSim/

BugReports https://github.com/DaphneGiorgi/IBMPopSim/issues

License MIT + file LICENSE

Depends R (>= 3.5.0)

Imports Rcpp (>= 0.12), checkmate, stats, readr, rlang, dplyr (>= 0.8.0), ggplot2

Suggests RcppArmadillo, knitr, rmarkdown, bookdown, ggfortify, magick, colorspace, gganimate, gridExtra

LinkingTo Rcpp

LazyData true

NeedsCompilation yes

VignetteBuilder knitr

RoxygenNote 7.3.1

Encoding UTF-8

Author Daphné Giorgi [aut, cre],
Sarah Kaakai [aut],
Vincent Lemaire [aut]

Repository CRAN

Date/Publication 2024-02-09 00:30:35 UTC

R topics documented:

`add_characteristic` *Generic method for add_characteristic*

Description

Generic method for add_characteristic

Usage

```
add_characteristic(x, name, value = NA)
```

Arguments

`x`	An object.
`name`	Name of the characteristic to add.
`value`	Value of the characteristic. By default `NA`.

`add_characteristic.population`
Add characteristic to a population

Description

Add characteristic to a population

Usage

```
## S3 method for class 'population'
add_characteristic(x, name, value = NA)
```

Arguments

x	Object of population class representing a population.
name	Name of the characteristic to add.
value	Value of the characteristic. By default NA.

`age_pyramid` *Generic method for age_pyramid*

Description

Generic method for age_pyramid

Usage

```
age_pyramid(object, time = 0, ages = c(0:110, Inf), ...)
```

Arguments

object	Population.
time	The age pyramid is computed at instant time. Must be a numeric greater than or equal to 0.
ages	*(Optional)* A numeric vector of distinct positive values composing age groups. Must be in increasing order.
...	Additional parameters

Value

An object of class pyramid containing the age pyramid of a population at instant time.

`age_pyramid.population` *Age pyramid from a population at a given time.*

Description

Reduce a population containing all individuals (with some characteristics) to an age-groups data frame (preserving characteristics). The function computes the number of individuals at time in each age group [ages[i],ages[i+1][, for i in {1,...,N-1}.

Usage

```
## S3 method for class 'population'
age_pyramid(object, time = 0, ages = c(0:110, Inf), ...)
```

Arguments

object	Object of population class representing a population.
time	The age pyramid is computed at instant time. Must be a numeric greater than or equal to 0.
ages	*(Optional)* A numeric vector of distinct positive values composing age groups. Must be in increasing order.
...	Additional parameters

Value

An object of class pyramid containing the age pyramid of the given population at instant time.

See Also

age_pyramids.population

Examples

```
age_pyramid(population(EW_pop_14$sample), time = 0)

age_pyramid(population(EW_popIMD_14$sample), time = 0, ages = seq(0, 120, by=2))
```

---

age_pyramids *Generic method for age_pyramids*

Description

Generic method for age_pyramids

Usage

```
age_pyramids(object, time = 0, ages = c(0:110, Inf))
```

Arguments

object	Population.
time	The age pyramid is computed at instant time. Must be a numeric greater than or equal to 0.
ages	*(Optional)* A numeric vector of distinct positive values composing age groups. Must be in increasing order.

age_pyramids.population

Age pyramid from a population data frame at some given times.

Description

Vectorial version in time of the function age_pyramid.population. Not compatible with IBMs including swap events.

Usage

```
## S3 method for class 'population'
age_pyramids(object, time = 0, ages = c(0:110, Inf))
```

Arguments

object	Object of population class representing a population.
time	The age pyramid is computed at instant time. Must be a numeric greater than or equal to 0.
ages	*(Optional)* A numeric vector of distinct positive values composing age groups. Must be in increasing order.

Details

For convenience. This is a just a lapply call of age_pyramid.population on the vector time.

check_intensity_code *Check the intensity code.*

Description

Verifies that the intensity contains the string 'result'.

Usage

```
check_intensity_code(code)
```

Arguments

code	String containing the intensity code.

check_interaction_code *Check the interaction code.*

Description

Verifies that the interaction contains the string 'result'.

Usage

```
check_interaction_code(code)
```

Arguments

code	String containing the interaction code.

check_kernel_code *Check the kernel code.*

Description

Verifies the kernel code.

Usage

```
check_kernel_code(code)
```

Arguments

code	String containing the kernel code.

compatibility_chars_events *Check characteristics-events compatibility*

Description

A function to check the compatibility between characteristics and events

Usage

```
compatibility_chars_events(characteristics, events)
```

Arguments

characteristics	List of characteristics
events	List of events

---

compatibility_pop_model *Check population-model compatibility*

Description

A function to check the compatibility between a population and a model

Usage

```
compatibility_pop_model(pop, model)
```

Arguments

pop	An object of class population
model	An Individual Based Model created with the mk_model function

---

death_table *Death table*

Description

Creates a death table from a population object. For each `i=1..N-1` and `j=1..M`, the number of individuals with age at last birthday in `[ages[i],ages[i+1])` and died in `[times[j],times[j+1])` is computed.

Usage

```
death_table(pop, ages, period)
```

Arguments

pop	Object of class `population`.
ages	A vector of size `N` composed of age groups.
period	A vector of size `M` composed of time intervals.

Details

The function computes the number of death in each time interval `[times[j],times[j+1])`, `j=1..M`.

Value

A death table matrix.

Examples

```
dth_table <-  death_table(population(EW_pop_out), 0:101, 0:11)
```

`EWdata_hmd` *England and Wale mortality data (source: Human Mortality Database)*

Description

Obtained with

`EWdata_hmd <- hmd.mx(country = "GBRTENW", username = ... , password = ...,label = "England and Wales")`

Usage

```
EWdata_hmd
```

Format

An object of class `demogdata` of length 7.

`EW_popIMD_14` *England and Wales (EW) 2014 population and death rates by Index of Multiple Deprivation (IMD).*

Description

EW population, death rates by age, gender and IMD for year 2014 (Source: Office for National Statistics, reference number 006518).

Usage

```
EW_popIMD_14
```

Format

A list containing:

`age_pyramid` Data frame containing EW age pyramid for year 2014, by gender, IMD and single year of age (0-115).

Individuals in the age class 90+ are distributed in the single year of age classes as in the EW population.

`death_rates` List containing 4 fields:

`male` Male death rates data frame, by IMD and single year of age (0-90+).

`female` Female death rates dataframe, by IMD and single year of age (0-90+).

`sample` Population dataframe composed of 100 000 individuals, sampled from `age_pyramid`.

EW_pop_14 *England and Wales (EW) 2014 population, death and birth rates.*

Description

EW 2014 population and death rates by age and gender (Source: Office for National Statistics, reference number 006518).

Female birth rates by age of the mother (Source: Office for National Statistics birth summary tables).

Usage

```
EW_pop_14
```

Format

A list containing:

`age_pyramid` Data frame containing EW age pyramid for year 2014, by gender and single year of age (0-115).

`rates` A list containing three data frames:

`birth` Birth rates data frame, by age of mother and 5 years age groups.

`death_male` Male death rates data frame, by single year of age (0-90+).

`death_female` Female death rates dataframe, by single year of age (0-90+).

`sample` Population dataframe composed of 100 000 individuals, sampled from `age_pyramid`.

EW_pop_out *Example of "human population" after 100 years of simulation.*

Description

Example of "human population" data frame after 100 years of simulation, based on a sample of England and Wales 2014 population and demographic rates.

Usage

```
EW_pop_out
```

Format

Data frame containing a population structured by age and gender, simulated with an initial population of 100 000 individuals sampled from `EW_pop_14$age_pyramid` over 100 years, with birth and death events.

exposure_table *Exposure table*

Description

Returns the Central Exposure-to-Risk for given ages groups and time period. The central Exposure-to-risk is computed as the sum of the time spent by individuals in a given age group over a given period, where age is the age at last birthday.

Usage

```
exposure_table(pop, ages, period)
```

Arguments

`pop`	Object of class `population`.
`ages`	A vector of size `N` composed of age groups.
`period`	A vector of size `M` composed of time intervals.

Details

The function computes the central exposure-to-risk in each time interval `[t[j],t[j+1])`, `j=1..M`, and age groups.

Value

An exposure matrix

Examples

```
ex_table <- exposure_table(population(EW_pop_out),0:101,0:11)
```

`get_characteristics` *Generic method for get_characteristics*

Description

Generic method for get_characteristics

Usage

```
get_characteristics(object, ...)
```

Arguments

`object`	An object.
`...`	Additional parameters.

`get_characteristics.population`
Returns names and C types of the characteristics.

Description

Returns names and C types of the characteristics (other than birth and death) of the individuals in a population, from a population data frame.

Usage

```
## S3 method for class 'population'
get_characteristics(object, ...)
```

Arguments

`object`	Object of population class representing a population.
`...`	additional arguments.

Value

Named vector composed of characteristics names and C types. If the population has no characteristics, which means that it has only the `birth` and `death` columns, this returns `NULL`.

Examples

```
get_characteristics(population(EW_pop_14$sample))
```

gompertz *Gompertz–Makeham intensity function.*

Description

The intensity function (or hazard function) for the Gompertz-Makeham law of mortality distribution is defined as

$$h(x) = \alpha e^{\beta x} + \lambda$$

with $\alpha, \beta, \lambda \in R_+$.

Usage

```
gompertz(alpha, beta, lambda = 0)
```

Arguments

alpha	Non-negative real parameter.
beta	Non-negative real parameter.
lambda	Non-negative real parameter.

Details

A C++ version of this function is available. See `vignette('IBMPopSim_cpp')` for more details.

Value

Function which associates x to $\alpha exp(\beta x) + \lambda$.

See Also

https://en.wikipedia.org/wiki/Gompertz%E2%80%93Makeham_law_of_mortality

linfun *Linear interpolation function.*

Description

Return a function performing the linear interpolation.

Usage

```
linfun(x, y, yleft = y[1], yright = y[length(y)])
```

Arguments

x, y	Numeric vectors giving the coordinates of the points to be interpolated.
yleft	The value to be returned when input x values are less than min(x).
yright	The value to be returned when input x values are greater than max(x).

Details

A C++ version of this function is available. See vignette('IBMPopSim_cpp') for more details.

Value

Objet of class linfun and function which is an approxfun function with method = 'linear'.

---

max.stepfun *Returns the maximum of a function of class* stepfun.

Description

Returns the maximum of a function of class stepfun.

Usage

```
## S3 method for class 'stepfun'
max(..., na.rm = FALSE)
```

Arguments

...	argument of class stepfun
na.rm	a logical indicating whether missing values should be removed

Value

The maximum of the step function.

merge_pop_withid — *A function returning a merged dataframe from a list of population dataframes with id.*

Description

A function returning a merged dataframe from a list of population dataframes with id.

Usage

```
merge_pop_withid(pop_df_list, chars_tracked = NULL)
```

Arguments

pop_df_list	A list of population dataframe where the first three columns of each dataframe are id, birth and death.
chars_tracked	A vector of characteristics to be tracked over time.

Value

A dataframe composed of all individuals with their characteristics at each simulation time.

mk_event_individual — *Creating an event with intensity of class individual*

Description

Creates an event with intensity of class individual (without interactions). When the event occurs, something happens to an individual `I` in the population. The created event must be used with `mk_model`.

Usage

```
mk_event_individual(type, name, intensity_code, kernel_code = "")
```

Arguments

type	Must be one of `'birth'`, `'death'`, `'entry'`, `'exit'`, `'swap'` or `'custom'`. See details.
name	*(Optional)* If not specified, the name given to the event is its type.
intensity_code	String containing some C++ code describing the intensity function. See details.
kernel_code	String containing some C++ code describing the event action. Optional for `'birth'`, `'death'` and `'exit'` events. See details.

Details

The type argument is one of the following

'birth' By default, a new individual newI is created, with the same characteristics of the parent I and birth date equal to the current time. Optional code can be precised in kernel_code.

'death' By default, the individual I dies. Optional code can be precised in kernel_code.

'entry' A new individual newI is added to the population, and its characteristics have to be defined by the user in the entry kernel_code.

'exit' An individual I exits from the population. Optional code can be precised in kernel_code.

'swap' The user can change the characteristics of the selected individual I. This requires kernel_code.

'custom' None of the above types, the user defines kernel_code that can act on the selected individual I and on the population pop.

The intensity_code argument is a string containing some C++ code describing the event intensity for individual I at time t. The intensity value **must be stored** in the variable result. Some of available variables in the C++ code are: t (the current time), I (the current individual selected for the event), the name of the model parameters (some variables, or functions, see mk_model). See vignette('IBMPopSim_Cpp') for more details.

The kernel_code argument is a string containing some C++ code which describing the action of the event. Some of available variables in the C++ code are: t (the current time), pop (the current population), I (the current individual selected for the event), newI (the new individual if 'birth' or 'entry' event), the name of the model parameters (some variables, or functions, see mk_model). See vignette('IBMPopSim') for more details.

Value

An S3 object of class event of type individual.

See Also

mk_model, mk_event_poisson, mk_event_inhomogeneous_poisson, and mk_event_interaction.

Examples

```
params <- list("p_male"= 0.51,
               "birth_rate" = stepfun(c(15,40), c(0,0.05,0)),
               "death_rate" = gompertz(0.008, 0.02))

death_event <- mk_event_individual(type = "death",
                name = "my_death_event",
                intensity_code = "result = death_rate(age(I,t));")

birth_event <- mk_event_individual(type = "birth",
                intensity_code = "if (I.male) result = 0;
                                  else result = birth_rate(age(I,t));",
                kernel_code = "newI.male = CUnif(0, 1) < p_male;")
```

mk_event_inhomogeneous_poisson
Creating inhomogeneous Poisson class event

Description

The function mk_event_inhomogeneous_poisson is used to create an event with intensity type inhomogeneous Poisson (time dependent intensity which does not depend on population). When the event occurs, something happens in the population. The created event must be used with mk_model.

Usage

```
mk_event_inhomogeneous_poisson(type, name, intensity_code, kernel_code = "")
```

Arguments

type	Must be one of 'birth', 'death', 'entry', 'exit', 'swap' or 'custom'. See details.
name	*(Optional)* If not specified, the name given to the event is its type.
intensity_code	String containing some C++ code describing the intensity function. See details.
kernel_code	String containing some C++ code describing the event action. Optional for 'birth', 'death' and 'exit' events. See details.

Details

The type argument is one of the following

'birth' By default, a new individual newI is created, with the same characteristics of the parent I and birth date equal to the current time. Optional code can be precised in kernel_code.

'death' By default, the individual I dies. Optional code can be precised in kernel_code.

'entry' A new individual newI is added to the population, and its characteristics have to be defined by the user in the entry kernel_code.

'exit' An individual I exits from the population. Optional code can be precised in kernel_code.

'swap' The user can change the characteristics of the selected individual I. This requires kernel_code.

'custom' None of the above types, the user defines kernel_code that can act on the selected individual I and on the population pop.

The intensity_code argument is a string containing some C++ code describing the event intensity for individual I at time t. The intensity value **must be stored** in the variable result. Some of available variables in the C++ code are: t (the current time), I (the current individual selected for the event), the name of the model parameters (some variables, or functions, see mk_model). See vignette('IBMPopSim_Cpp') for more details.

The kernel_code argument is a string containing some C++ code which describing the action of the event. Some of available variables in the C++ code are: t (the current time), pop (the current population), I (the current individual selected for the event), newI (the new individual if 'birth' or 'entry' event), the name of the model parameters (some variables, or functions, see mk_model). See vignette('IBMPopSim') for more details.

Value

An S3 object of class `event` of type inhomogeneous Poisson.

See Also

`mk_model`, `mk_event_poisson`, `mk_event_individual`, `mk_event_interaction`.

`mk_event_interaction` *Creating an event with intensity of type interaction*

Description

Creates an event whose intensity depends on an individual and interactions with the population. When the event occurs, something happens to an individual `I` in the population. The intensity of the event can depend on time, the characteristics of I and other individuals in the population, and can be written as

$$d(I, t, pop) = \sum_{J \in pop} U(I, J, t),$$

where U is called the interaction function. The created event must be used with `mk_model`.

Usage

```
mk_event_interaction(
  type,
  name,
  interaction_code,
  kernel_code = "",
  interaction_type = "random"
)
```

Arguments

`type`	Must be one of `'birth'`, `'death'`, `'entry'`, `'exit'`, `'swap'` or `'custom'`. See details.
`name`	*(Optional)* If not specified, the name given to the event is its type.
`interaction_code`	String containing some C++ code describing the interaction function. See details.
`kernel_code`	String containing some C++ code describing the event action. Optional for `'birth'`, `'death'` and `'exit'` events. See details.
`interaction_type`	*(Optional)* Either `'random'` or `'full'`. By default `'random'` which is faster than `'full'`.

Details

The type argument is one of the following

'birth' By default, a new individual newI is created, with the same characteristics of the parent I and birth date equal to the current time. Optional code can be precised in kernel_code.

'death' By default, the individual I dies. Optional code can be precised in kernel_code.

'entry' A new individual newI is added to the population, and its characteristics have to be defined by the user in the entry kernel_code.

'exit' An individual I exits from the population. Optional code can be precised in kernel_code.

'swap' The user can change the characteristics of the selected individual I. This requires kernel_code.

'custom' None of the above types, the user defines kernel_code that can act on the selected individual I and on the population pop.

The interaction_code argument is a string containing some C++ code describing the event interaction function U at time t. The interaction value **must be stored** in the variable result. Some of available variables in the C++ code are: t (the current time), I (the current individual selected for the event), J (another individual if interaction_type is 'random'), the name of the model parameters (some variables, or functions, see mk_model). See vignette('IBMPopSim_Cpp') for more details.

The kernel_code argument is a string containing some C++ code which describing the action of the event. Some of available variables in the C++ code are: t (the current time), pop (the current population), I (the current individual selected for the event), newI (the new individual if 'birth' or 'entry' event), the name of the model parameters (some variables, or functions, see mk_model). See vignette('IBMPopSim') for more details.

Value

An S3 object of class event of type interaction.

See Also

mk_model, mk_event_poisson, mk_event_inhomogeneous_poisson, mk_event_individual.

Examples

```
death_interaction_code<- " result = max(J.size -I.size,0);"
event <- mk_event_interaction(type="death",
                              interaction_code = death_interaction_code)
```

mk_event_poisson *Creating Poisson class event*

Description

The function mk_event_poisson is used to create an event with intensity of type Poisson (constant intensity which does not depend on population or time). When the event occurs, something happens in the population. The created event must be used with mk_model.

Usage

```
mk_event_poisson(type, name, intensity, kernel_code = "")
```

Arguments

type	Must be one of 'birth', 'death', 'entry', 'exit', 'swap' or 'custom'. See details.
name	*(Optional)* If not specified, the name given to the event is its type.
intensity	String containing some constant positive value, or name of a parameter which is a constant positive value.
kernel_code	String containing some C++ code describing the event action. Optional for 'birth', 'death' and 'exit' events. See details.

Details

The type argument is one of the following

'birth' By default, a new individual newI is created, with the same characteristics of the parent I and birth date equal to the current time. Optional code can be precised in kernel_code.

'death' By default, the individual I dies. Optional code can be precised in kernel_code.

'entry' A new individual newI is added to the population, and its characteristics have to be defined by the user in the entry kernel_code.

'exit' An individual I exits from the population. Optional code can be precised in kernel_code.

'swap' The user can change the characteristics of the selected individual I. This requires kernel_code.

'custom' None of the above types, the user defines kernel_code that can act on the selected individual I and on the population pop.

The kernel_code argument is a string containing some C++ code which describing the action of the event. Some of available variables in the C++ code are: t (the current time), pop (the current population), I (the current individual selected for the event), newI (the new individual if 'birth' or 'entry' event), the name of the model parameters (some variables, or functions, see mk_model). See vignette('IBMPopSim') for more details.

Value

An S3 object of class event of type Poisson.

See Also

mk_model, mk_event_inhomogeneous_poisson, mk_event_individual, mk_event_interaction.

Examples

```
birth <- mk_event_poisson('birth', intensity = 10)


params <- list(beta = 10)
death <- mk_event_poisson('death', intensity = 'beta') # name of one parameter
mk_model(events = list(birth, death), parameters = params)
```

---

mk_model *Creates a model for IBMPopSim.*

Description

This function creates an Individual Based Model describing the population, events which can occur in the population, and the model parameters.

Usage

```
mk_model(
  characteristics = NULL,
  events,
  parameters = NULL,
  with_compilation = TRUE
)
```

Arguments

characteristics	List containing names and types of characteristics of individuals in the population. See get_characteristics.
events	List of events in the model. See mk_event_poisson, mk_event_inhomogeneous_poisson, mk_event_individual, and mk_event_interaction.
parameters	Model parameters. A list of parameters of the model.
with_compilation	*(Optional)* Logical parameter, TRUE by default. If FALSE the sourceCpp function is not called.

Details

It builds the C++ model code and produces the function popsim_cpp which will be used for simulating the model. The function used to simulate a population from a model is popsim.

Value

model List containing the built model :

- individual_type: Names and types (R and C++) of characteristics.
- parameters_types: Names and types (R and C++) of model parameters.
- events: List of events.
- cpp_code: Output of C++ compilation.

See Also

popsim, mk_event_poisson, mk_event_individual, mk_event_interaction.

Examples

```
params <- list("p_male"= 0.51,
               "birth_rate" = stepfun(c(15,40),c(0,0.05,0)),
               "death_rate" = gompertz(0.008,0.02))

death_event <- mk_event_individual(type = "death",
                                   intensity_code = "result = death_rate(age(I,t));")

birth_event <- mk_event_individual(type = 'birth',
                                   intensity_code = "if (I.male) result = 0;
                                     else result=birth_rate(age(I,t));",
                                   kernel_code = "newI.male = CUnif(0, 1) < p_male;")

model <- mk_model(characteristics = get_characteristics(population(EW_pop_14$sample)),
                  events = list(death_event,birth_event),
                  parameters = params)

summary(model)
```

---

piecewise_x *Piecewise real function.*

Description

Given the vectors (breaks[1],...,breaks[n]) and the list of IBMPopSim compatible functions funs = (f[0],f[1],...,f[n]) (one value more!), piecewise_x(breaks, funs) returns the function

$$f(x) = f_0(x)1_{x \leq breaks[1]} + \sum_{k=1}^{n-1} f_k(x)1_{[breaks_k, breaks_{k+1})}(x) + f_n(x)1_{x \geq breaks[n]}$$

Usage

```
piecewise_x(breaks, funs)
```

Arguments

breaks	Numeric vector giving the breaks of functions given in funs. Must be sorted with unique values.
funs	List of functions.

Details

A C++ version of this function is available. See `vignette('IBMPopSim_cpp')` for more details.

Value

Piecewise function built with the given intervals and functions.

Examples

```
dr <- with(EW_pop_14$rates,
           stepfun(x=death_male[,"age"], y=c(0,death_male[,"value"])))
# before age 80 the stepfun and after age 80 the gompertz function
f <- piecewise_x(80, list(dr, gompertz(0.00006, 0.085)))
x <- seq(40:120)
plot(x, sapply(x, f))
```

---

piecewise_xy *Piecewise real function of two variables.*

Description

Given the vectors `(breaks[1],...,breaks[n])` and the list of IBMPopSim compatible functions `funs = (f[0],f[1],...,f[n])` (one value more!), `piecewise_xy(breaks, funs)` returns the function

$$f(x,y) = f_0(x)1_{y \leq breaks[1]} + \sum_{k=1}^{n-1} f_k(x)1_{[breaks_k, breaks_{k+1})}(y) + f_n(x)1_{y \geq breaks[n]}$$

Usage

```
piecewise_xy(breaks, funs)
```

Arguments

breaks	Numeric vector giving the breaks of functions given in funs. Must be sorted with unique values.
funs	List of functions.

Details

A C++ version of this function is available. See `vignette('IBMPopSim_cpp')` for more details.

Value

Piecewise bivariate function built with the given intervals and functions.

Examples

```
time_dep_function <- piecewise_xy(c(5),
                                  list(gompertz(0.1, 0.005), gompertz(0.08, 0.005)))
time_dep_function(0, 65)  # death intensity at time 0 and age 65.
```

`plot.population` *Plot the age pyramid of a population data frame (at a given time).*

Description

Plot an age pyramid from age pyramid data frame with possibly several characteristics.

Usage

```
## S3 method for class 'population'
plot(
  x,
  group_colors = NULL,
  group_legend = "Group",
  age_breaks = NULL,
  value_breaks = NULL,
  ...
)
```

Arguments

`x`	Object of class population.
`group_colors`	*(Optional)* Named character vector.
`group_legend`	*(Optional)* Legend title name. By default set to `"Group"`.
`age_breaks`	*(Optional)* An ordered vector of indexes of vector `unique(pyr$age)` used for breaks for the axis of ages.
`value_breaks`	*(Optional)* Breaks for the axis of values.
`...`	Additional arguments

Value

Plot of age pyramid.

See Also

plot.pyramid, age_pyramid.population.

Examples

```
plot(population(EW_pop_14$sample), time = 0)
```

---

plot.pyramid *Plot an age pyramid.*

Description

Plot an age pyramid from age pyramid data frame with possibly several characteristics.

Usage

```
## S3 method for class 'pyramid'
plot(
  x,
  group_colors = NULL,
  group_legend = "Group",
  age_breaks = NULL,
  value_breaks = NULL,
  ...
)
```

Arguments

x	Object of class pyramid. *(Optional)* For plotting an age pyramid composed of several subgroups, the population data frame must contain a column named group_name.
group_colors	*(Optional)* Named character vector.
group_legend	*(Optional)* Legend title name. By default set to "Group".
age_breaks	*(Optional)* An ordered vector of indexes of vector unique(pyr$age) used for breaks for the axis of ages.
value_breaks	*(Optional)* Breaks for the axis of values.
...	Additional parameters

Value

Plot of the age pyramid.

See Also

plot.population

Examples

```
plot.pyramid(subset(pyramid(EW_pop_14$age_pyramid), as.numeric(age) <= 110))


library(colorspace)
pyr_IMD <- subset(pyramid(EW_popIMD_14$age_pyramid), as.numeric(age) <= 110)
pyr_IMD$group_name <- with(pyr_IMD, ifelse(male, paste('Males - IMD', IMD),
                          paste('Females - IMD', IMD)))
colors <- c(sequential_hcl(n=5, palette = "Magenta"),
            sequential_hcl(n=5, palette = "Teal"))
names(colors) <- c(paste('Females - IMD', 1:5),
                   paste('Males - IMD', 1:5))
# note that you must have setequal(names(colors), pyr_IMD$group_name) is TRUE
plot.pyramid(pyr_IMD, colors)

# age pyramids at different times
library(gganimate)
pyrs = age_pyramids(population(EW_popIMD_14$sample), time = 1:10)
plot.pyramid(pyrs) + transition_time(time) + labs(title = "Time: {frame_time}")
```

---

popsample *Generic method for popsample*

Description

Generic method for popsample

Usage

```
popsample(age_pyramid, size, age_max = 120, time = 0)
```

Arguments

age_pyramid	Age pyramid.
size	A non-negative integer giving the number of individuals in population.
age_max	*(Optional)* A non-negative numeric which replace (if exists) the Inf in age_pyramid.population.
time	*(Optional)* The age pyramid is computed at instant time. Must be a numeric greater than or equal to 0.

Value

Object of population class representing a data frame of size size containing a population of individuals.

`popsample.pyramid` *Sample a population from an age pyramid (at a given time).*

Description

Sample a population from an age pyramid (at a given time).

Usage

```
## S3 method for class 'pyramid'
popsample(age_pyramid, size, age_max = 120, time = 0)
```

Arguments

`age_pyramid`	Object of `pyramid` class.
`size`	A non-negative integer giving the number of individuals in population.
`age_max`	*(Optional)* A non-negative numeric which replace (if exists) the `Inf` in `age_pyramid.population`.
`time`	*(Optional)* The age pyramid is computed at instant `time`. Must be a numeric greater than or equal to 0.

Value

Object of `population` class representing a data frame of size `size` containing a population of individuals.

Examples

```
pop_sample_1e4 <- popsample(pyramid(EW_pop_14$age_pyramid), size = 1e4)
```

`popsim` *Simulation of a model.*

Description

This function simulates the random evolution of an IBM.

Usage

```
popsim(
  model,
  initial_population,
  events_bounds,
  parameters = NULL,
  age_max = Inf,
  time,
  multithreading = FALSE,
  num_threads = NULL,
  clean_step = NULL,
  clean_ratio = 0.1,
  seed = NULL,
  verbose = FALSE
)
```

Arguments

`model`	Model resulting from a call to the function `mk_model`.
`initial_population`	Object of population class representing the initial population.
`events_bounds`	Named vector of events bounds, with names corresponding to events names.
`parameters`	List of model parameters.
`age_max`	Maximum age of individuals in the population (`Inf` by default).
`time`	Final time (Numeric). Can be of length 1 or a vector of simulation discretized times.
`multithreading`	Logical for multithread activation, `FALSE` by default. Should be only activated for IBM simulation with no interactions.
`num_threads`	*(Optional)* Number of threads used for multithreading. Set by default to the number of concurrent threads supported by the available hardware implementation.
`clean_step`	*(Optional)* Optional parameter for improving simulation time. Time step for removing dead (or exited) individuals from the population. By default, equal to age_max.
`clean_ratio`	*(Optional)* Optional parameter for improving simulation time. 0.1 by default.
`seed`	*(Optional)* Random generator seed, random by default.
`verbose`	*(Optional)* Activate verbose output, FALSE by default.

Value

List composed of

arguments Simulation inputs (initial population, parameters value, multithreading...)

logs Simulation logs (algorithm duration, accepted/rejected events...).

population If `time` is of length 1, population is an object of type population containing of all individuals who lived in the population in the time interval `[0,time]`. If `time` is a vector (`time[1], ..., time[n]`), `population` is a list of `n` objects of type population, each representing the state of the population at time `time[i]`, for `i = 1,..., n`.

See Also

`mk_model`.

Examples

```
init_size <- 100000
pop_df <- data.frame(birth = rep(0, init_size), death = NA)
pop <- population(pop_df)

birth = mk_event_poisson(type = 'birth', intensity = 'lambda')
death = mk_event_poisson(type = 'death', intensity = 'mu')
params = list('lambda' = 100, 'mu' = 100)
birth_death <- mk_model(events = list(birth, death),
                        parameters = params)

sim_out <- popsim(model = birth_death,
                  initial_population = pop,
                  events_bounds = c('birth' = params$lambda, 'death' = params$mu),
                  parameters = params,
                  time = 10)
```

`population` *Class population*

Description

Data frame containing a population, with at least a birth and a death column, and eventually some other characteristics

Usage

```
population(x, entry = FALSE, out = FALSE, id = FALSE)
```

Arguments

`x`	Data frame or list of data frames, containing at least a birth and a death column
`entry`	Boolean flag. By default set to FALSE. If set to TRUE the population must contain a column of numerical values named "entry", If the column doesn't exist a column named "entry" is added to the data frame with all values set to NA.

out	Boolean flag. By default set to FALSE. If set to TRUE the population must contain a column of boolean values named "out", If the column doesn't exist a column named "out" is added to the data frame with all the values set to FALSE.
id	Boolean flag. By default set to FALSE. If set to TRUE the population must contain a column of integer distinct values named "id". If the column doesn't exist a column named "id" is added to the data frame with values seq(1, nrow(x)).

Value

Given data frame augmented of the "population" class. If a list of data frames is given, the column names should contain the string "id" and the list corresponds to the evolution of a population at different times. The constructor then returns the last population observed in the list (corresponding to the final state of the population).

`population_alive` *Generic method for population_alive*

Description

Generic method for population_alive

Usage

```
population_alive(object, t, a1 = 0, a2 = Inf, ...)
```

Arguments

object	A population.
t	A numeric indicating the time at which alive individuals are observed.
a1	0 by default. Lower bound for age.
a2	Inf by default. Upper bound for age.
...	Additional params.

Value

All individuals alive at time `t` and of age in `[a1,a2)`.

population_alive.population *Returns a population of individuals alive.*

Description

Returns a population of individuals alive.

Usage

```
## S3 method for class 'population'
population_alive(object, t, a1 = 0, a2 = Inf, ...)
```

Arguments

object	A population data frame containing at least a column birth and death.
t	A numeric indicating the time.
a1	0 by default. All individuals of age over a1 at t are selected.
a2	Inf by default. All individuals of age below a2 at t are selected.
...	Additional params.

Value

The function returns a population data frame containing all individuals alive at time t and of age in [a1,a2).

print.event *Print Event*

Description

print method for class "event" giving a short description of an event.

Usage

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

Arguments

x	Argument of class event.
...	Additional arguments affecting the summary produced.

print.model *Printing of a model*

Description

`print` method for class `model`.

Usage

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

Arguments

`x`	argument of class `model`
`...`	additional arguments affecting the summary produced.

print.population *Printing population*

Description

Print a population

Usage

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

Arguments

`x`	Object of population class representing a population.
`...`	Additional arguments

Value

Print the population

pyramid *Class pyramid*

Description

Data frame containing an age pyramid, with at least an `age` and a `value` column, and eventually some other characteristics. If a `male` column is present, it must be a logical vector, if a `group` column is present, it must be a vector of type character.

Usage

```
pyramid(x)
```

Arguments

`x`	Data frame, containing at least an `age` and a `value` column

Value

Given data frame augmented of the "age_pyramid" class.

stepfun *Step Function.*

Description

Given the vectors `(x[1],...,x[n])` and `(y[0],y[1],...,y[n])` (one value more!), `stepfun(x, y)` returns an interpolating step function, say `f_n`. This is the cadlag version (`right = FALSE`) of the `stepfun` function from package `stats`. The step function value `f_n(t)` equals to the constant `y[k-1]` for `t` in `[x[k-1], x[k])` so that

$$f_n(t) = \sum_{k=1}^{n+1} y_{k-1} 1_{[x_{k-1}, x_k)}(t),$$

with$x_0 = -\infty$ and $x_{n+1} = +\infty$.

Usage

```
stepfun(x, y)
```

Arguments

`x`	Numeric vector giving the knots or jump locations of the step function. Must be sorted with unique values.
`y`	Numeric vector one longer than x, giving the heights of the function values between the cx values.

Details

This function is defined for documentation purposes only. See stepfun and approxfun.

A C++ version of this function is available. See vignette('IBMPopSim_cpp') for more details.

Value

Objet of class stepfun with option right = FALSE (cadlag function).

See Also

plot.stepfun and max.stepfun.

---

summary.event *Summarizing an event*

Description

summary method for class event giving a detailed description of an event.

Usage

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

Arguments

object	Argument of class event.
...	Additional arguments affecting the summary produced.

---

summary.logs *Summary logs*

Description

Summary of the logs of a simulation

Usage

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

Arguments

object	Logs of the output of a call to popsim function
...	Additional arguments affecting the summary produced

Value

Print column names and number of individuals

`summary.model` *Summary of a model*

Description

`summary` method for class `model`.

Usage

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

Arguments

`object`	argument of class `model`
`...`	additional arguments affecting the summary produced.

`summary.population` *Summary population*

Description

Summary of a population with column names and number of individuals

Usage

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

Arguments

`object`	Object of population class representing a population.
`...`	Additional arguments affecting the summary produced

Value

Print column names and number of individuals

summary.simulation_output *Summary simulation output*

Description

Summary of a simulation output

Usage

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

Arguments

object	Output of a call to popsim function
...	Additional arguments affecting the summary produced

Value

Summary of population(s) and the logs

toy_params *Toy parameters for IBMPopSim-human_popIMD vignette example.*

Description

Toy parameters for IBMPopSim-human_popIMD vignette example.

Usage

```
toy_params
```

Format

A list containing:

birth A list of 3 numeric vectors (alpha, beta, TFR_weights) for creating birth intensity with the Weibull probability density function.

swap A List of one numeric vector and two data frames (ages, intensities and distribution) for creating the swap intensity and kernel functions.

`weibull` *Weibull function.*

Description

The Weibull (density) function is defined as

$$h(x) = (\frac{k}{\lambda})(\frac{x}{\lambda})^{k-1} e^{-(x/\lambda)^k}$$

with $k, \lambda \in (0, +\infty)$.

Usage

```
weibull(k, lambda = 1)
```

Arguments

`k`	Shape parameter, a positive real number.
`lambda`	Scale parameter, a positive real number, defaults to 1.

Details

A C++ version of this function is available. See `vignette('IBMPopSim_cpp')` for more details.

Value

The Weibull density function `dweibull` with shape parameter `k` and scale parameter `lambda`, see `dweibull`.

See Also

https://en.wikipedia.org/wiki/Weibull_distribution

Index