Package 'lifecontingencies'

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Type Package

Title Financial and Actuarial Mathematics for Life Contingencies

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Description Classes and methods that allow the user to manage life table, actuarial tables (also multiple decrements tables). Moreover, functions to easily perform demographic, financial and actuarial mathematics on life contingencies insurances calculations are contained therein. See Spedicato (2013) <doi:10.18637/jss.v055.i10>.

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`lifecontingencies-package`

Package to perform actuarial mathematics on life contingencies and classical financial mathematics calculations.

Description

The lifecontingencies package performs standard financial, demographic and actuarial mathematics calculation. The main purpose of the package is to provide a comprehensive set of tools to perform risk assessment of life contingent insurances.

Details

Some functions have been powered by Rcpp code.

Warning

This package and functions herein are provided as is, without any guarantee regarding the accuracy of calculations. The author disclaims any liability arising by any losses due to direct or indirect use of this package.

Note

Work in progress.

Author(s)

Giorgio Alfredo Spedicato with contributions from Reinhold Kainhofer and Kevin J. Owens Maintainer: <spedicato_giorgio@yahoo.it>

References

The lifecontingencies Package: Performing Financial and Actuarial Mathematics Calculations in R, Giorgio Alfredo Spedicato, Journal of Statistical Software, 2013,55 , 10, 1-36

See Also

accumulatedValue, annuity

Examples

```
##financial mathematics example

#calculates monthly installment of a loan of 100,000,
#interest rate 0.05

i=0.05
monthlyInt=(1+i)^(1/12)-1
Capital=100000
#Montly installment

R=1/12*Capital/annuity(i=i, n=10,k=12, type = "immediate")
R
balance=numeric(10*12+1)
capitals=numeric(10*12+1)
interests=numeric(10*12+1)
balance[1]=Capital
interests[1]=0
capitals[1]=0

for(i in (2:121)) {
   balance[i]=balance[i-1]*(1+monthlyInt)-R
   interests[i]=balance[i-1]*monthlyInt
   capitals[i]=R-interests[i]
   }
loanSummary=data.frame(rate=c(0, rep(R,10*12)),
 balance, interests, capitals)

head(loanSummary)

tail(loanSummary)

##actuarial mathematics example

#APV of an annuity

  data(soaLt)
```

```
soa08Act=with(soaLt, new("actuarialtable",interest=0.06,
x=x,lx=Ix,name="SOA2008"))
#evaluate and life-long annuity for an aged 65
axn(soa08Act, x=65)
```

`accumulatedValue` *Function to evaluate the accumulated value.*

Description

This function returns the value at time n of a series of equally spaced payments of 1.

Usage

```
accumulatedValue(i, n, m = 0, k = 1, type = "immediate")
```

Arguments

`i`	Effective interest rate expressed in decimal form. E.g. 0.03 means 3%.
`n`	Number of terms of payment.
`m`	Deferring period, whose default value is zero.
`k`	Frequency of payment.
`type`	The payment type. Use `"immediate"` (default) for an annuity-immediate, where payments are made at the end of each period, or `"due"` for an annuity-due, where payments are made at the beginning of each period. For compatibility, `"arrears"` is an alias for `"immediate"` and `"advance"` is an alias for `"due"` (can be abbreviated).

Details

The accumulated value is the future value of the terms of an annuity. Its mathematical expression is $s_{\overline{n}|} = (1+i)^n a_{\overline{n}|}$. The payment timing follows the `type` argument: an annuity-immediate has payments at the end of each period, while an annuity-due has payments at the beginning of each period.

Value

A numeric value representing the calculated accumulated value.

Warning

The function is provided as is, without any guarantee regarding the accuracy of calculation. We disclaim any liability for eventual losses arising from direct or indirect use of this software.

Note

Accumulated values are derived from annuities by the following basic equation $s_{\overline{n}|} = (1+i)^n = a_{\overline{n}|}$.

Author(s)

Giorgio A. Spedicato

References

Broverman, S.A., Mathematics of Investment and Credit (Fourth Edition), 2008, ACTEX Publications.

See Also

annuity

`actuarialtable-class` *Class* `"actuarialtable"`

Description

Objects of class `"actuarialtable"` inherit the structure of class `"lifetable"` adding just the slot for interest rate, `interest`.

Objects from the Class

Objects can be created by calls of the form `new("actuarialtable", ...)`. Creation is the same as lifetable objects creation, the slot for interest must be added too.

Slots

`interest`: Object of class `"numeric"` slot for interest rate, e.g. 0.03

`x`: Object of class `"numeric"` age slot

`lx`: Object of class `"numeric"` subjects at risk at age x

`name`: Object of class `"character"` name of the actuarial table

Extends

Class `"lifetable"`, directly.

Methods

coerce `signature(from = "actuarialtable", to = "data.frame")`: moves from `actuarialtable` to `data.frame`

coerce `signature(from = "actuarialtable", to = "numeric")`: coerce from `actuarialtable` to a numeric

getOmega `signature(object = "actuarialtable")`: as for `lifetable`

print `signature(x = "actuarialtable")`: tabulates the actuarial commutation functions

show `signature(object = "actuarialtable")`: show method

summary `signature(object = "actuarialtable")`: prints brief summary

Warning

The function is provided as is, without any warranty regarding the accuracy of calculations. The author disclaims any liability for eventual losses arising from direct or indirect use of this software.

Note

The interest slot will handle time-varying interest rates in the future.

Author(s)

Giorgio A. Spedicato

References

Actuarial Mathematics (Second Edition), 1997, by Bowers, N.L., Gerber, H.U., Hickman, J.C., Jones, D.A. and Nesbitt, C.J.

See Also

`axn`,`lifetable`

Examples

```
showClass("actuarialtable")
```

---

annuity *Annuity*

Description

This function calculates the present value of a stream of fixed payments separated by equal intervals of time.

Usage

```
annuity(i, n, m = 0, k = 1, type = "immediate")
```

Arguments

i	Effective interest rate expressed in decimal form. E.g. 0.03 means 3%. It can be a vector of interest rates of the same length of periods.
n	Periods for payments. If n = infinity then annuity returns the value of a perpetuity (either immediate or due).
m	Deferring period, whose default value is zero.
k	Yearly payments frequency. A payment of $k^{-}1$ is supposed to be performed at the end of each year.
type	The payment type. Use "immediate" (default) for an annuity-immediate, where payments are made at the end of each period, or "due" for an annuity-due, where payments are made at the beginning of each period. For compatibility, "arrears" is an alias for "immediate" and "advance" is an alias for "due" (can be abbreviated).

Details

For an annuity-immediate the first payment occurs at time $1/k$; for an annuity-due the first payment occurs at time 0. Thus, for annual payments, an annuity-immediate has payment times $1, 2, \ldots, n$, whereas an annuity-due has payment times $0, 1, \ldots, n-1$.

Value

A numeric value representing the present value of the annuity.

Note

The value returned by annuity function derives from direct calculation of the discounted cash flow and not from formulas, like $a^{(m)}{}_{\overline{n}|} = \frac{1-v^n}{i^{(m)}}$. When m is greater than 1, the payment per period is assumed to be $\frac{1}{m}$.

Author(s)

Giorgio A. Spedicato

References

Broverman, S.A., Mathematics of Investment and Credit (Fourth Edition), 2008, ACTEX Publications.

`arithmetic_variation_insurances` *Life insurance with arithmetic-variation benefit (increasing/decreasing, fractional claims)*

Description

This help page groups two term life insurances with **arithmetic variation** of the benefit, both with optional deferment `m` and `k` fractional claim times (claims at end of subperiods):

- **IAxn**: *increasing* arithmetic term insurance (benefit grows linearly with time);
- **DAxn**: *decreasing* arithmetic term insurance (benefit declines linearly with time).

Usage

```
IAxn(
  actuarialtable,
  x,
  n,
  i = actuarialtable@interest,
  m = 0,
  k = 1,
  type = "EV",
  power = 1
)

DAxn(
  actuarialtable,
  x,
  n,
  i = actuarialtable@interest,
  m = 0,
  k = 1,
  type = "EV",
  power = 1
)
```

Arguments

`actuarialtable`	A `lifetable` or `actuarialtable` object.
`x`	Attained age at inception.
`n`	Coverage length in years. If missing, it is set to `getOmega(actuarialtable) - x - m`.
`i`	Annual effective interest rate. Defaults to `actuarialtable@interest`.
`m`	Deferment (years). Default 0.

k	Fractional periods per year ($k \geq 1$). Default 1.
type	Output type: "EV" (expected value, default) or "ST" (one stochastic realization via rLifeContingencies).
power	Power applied to discounted cash flows before expectation (default 1).

Details

Let $t_j = m + (j-1)/k$, $j = 1, \ldots, nk$. With **fractional claims at end of subperiods**, the EV implementations follow the pattern already used in Axn:

IAxn (increasing):

$$\mathrm{IA}^{(k)}_{\overline{n}|} = \sum_{j=1}^{nk} \left(\frac{j}{k}\right) v^{t_j+1/k}\ {}_{t_j}p_x\ q^{(1/k)}_{x+t_j},$$

where $v = (1+i)^{-1}$, computed via pxt(...) and qxt(..., t=1/k).

DAxn (decreasing) is analogous with benefit $(n-(j-1)/k)$; see its subsection below.

DAxn (decreasing):

$$\mathrm{DA}^{(k)}_{\overline{n}|} = \sum_{j=1}^{nk} \left(n - \frac{j-1}{k}\right) v^{t_j+1/k}\ {}_{t_j}p_x\ q^{(1/k)}_{x+t_j}, \qquad t_j = m + \frac{j-1}{k}.$$

See "Fractional timing conventions" above for claim timing assumptions.

Value

A numeric value: the APV (or one simulated realization if type="ST").

IAxn — Increasing arithmetic term

Computes the APV of an n-year **increasing** term insurance on a life aged x, with k fractional claim times and optional deferment m. The benefit at the j-th subperiod equals j/k.

Fractional timing conventions

For **insurance** benefits in this package, fractional claims are assumed to occur at the **end** of each subperiod (i.e., at $t_j + 1/k$). This matches the implementation that multiplies survival to t_j and a fractional death probability over the next subperiod:

$$v^{t_j+1/k}\ {}_{t_j}p_x\ q^{(1/k)}_{x+t_j}.$$

By contrast, **annuities** use a payment-timing flag ("immediate" vs "due") which changes the evaluation times; insurance here has a fixed claim timing at end-subperiod.

DAxn — Decreasing arithmetic term

Computes the APV of an n-year **decreasing** term insurance on a life aged x, with k fractional claim times and optional deferment m. The benefit at the j-th subperiod equals $n-(j-1)/k$.

References

Bowers, N. L., Gerber, H. U., Hickman, J. C., Jones, D. A., Nesbitt, C. J. (1997). *Actuarial Mathematics*, 2nd ed., SOA.

See Also

Axn (level benefit), AExn, Exn, axn

Other life-contingency APVs: endowment_trio

Examples

```
## Setup (legacy examples)
data(soaLt)
soa08Act <- with(soaLt, new("actuarialtable", interest=0.06, x=x, lx=Ix, name="SOA2008"))

## IAxn: increasing arithmetic term, 10 years, age 25 (legacy)
IAxn(actuarialtable = soa08Act, x = 25, n = 10)

## More examples (k>1 and deferment)
IAxn(actuarialtable = soa08Act, x = 40, n = 20, k = 12)     # monthly claims
IAxn(actuarialtable = soa08Act, x = 40, n = 15, m = 5, k = 4) # deferred 5y, quarterly

## DAxn: decreasing arithmetic term, 10 years, age 25 (legacy)
DAxn(actuarialtable = soa08Act, x = 25, n = 10)
## More examples (k>1 and deferment)
DAxn(actuarialtable = soa08Act, x = 45, n = 10, k = 2)       # semiannual
DAxn(actuarialtable = soa08Act, x = 45, n = 12, m = 3, k = 12) # deferred 3y, monthly
```

---

autoplot.lifetable *Autoplot a life table*

Description

Produces a ggplot2 representation of the number of survivors by age. The method is defined for 'lifetable'; S3 dispatch also makes it available for S4 subclasses such as 'actuarialtable'.

Usage

```
## S3 method for class 'lifetable'
autoplot(object, ...)
```

Arguments

object	A 'lifetable' object, or an object inheriting from it.
...	Additional arguments passed to 'ggplot2::geom_line()'.

Value

A ‘ggplot2‘ plot object.

Examples

```
lt <- new("lifetable", x = 0:3, lx = c(100, 90, 50, 10))
ggplot2::autoplot(lt)
```

`Axn.mdt` *Multiple decrement insurances and annuities*

Description

`Axn.mdt` gives the actuarial present value (APV) of a term insurance on a multiple decrement table, paying at the end of the year of decrement a benefit that may depend on the cause of decrement. `axn.mdt` gives the APV of an annuity payable while the insured is still in the active (no decrement yet) state.

Usage

```
Axn.mdt(object, x, n, i, decrement, benefits = 1, m = 0)

axn.mdt(object, x, n, i, m = 0, k = 1, payment = "advance")
```

Arguments

`object`	an `mdt` object
`x`	policyholder's age (an integer age tabulated in `object`)
`n`	contract duration in years. If missing, the cover runs to the end of the table, i.e. $n = \omega + 1 - x - m$.
`i`	interest rate
`decrement`	decrement(s) covered: one or more names (or column indices) among `getDecrements(object)`. If missing, every decrement is covered (insurance on the total decrement (τ)).
`benefits`	benefit amounts, one per element of `decrement` (recycled). Default 1, i.e. a unit benefit for every covered cause.
`m`	deferment period in years (default 0).
`k`	number of annuity payments per year (default 1). Survival probabilities at fractional durations are interpolated linearly in $l_x^{(\tau)}$.
`payment`	`"advance"` (or `"due"`, default) or `"arrears"` (or `"immediate"`).

Details

With $v = (1+i)^{-1}$ the insurance APV is

$$\sum_{j \in J} b_j \sum_{h=0}^{n-1} v^{m+h+1} \, {}_{m+h}p_x^{(\tau)} \, q_{x+m+h}^{(j)},$$

which for a single cause reduces to the historical `Axn.mdt`. The annuity APV is $\frac{1}{k} \sum_h v^{t_h} \, {}_{t_h}p_x^{(\tau)}$, with payment times $t_h = m, m+1/k, \ldots, m+n-1/k$ (in advance) or $m+1/k, \ldots, m+n$ (in arrears). Benefit premiums and reserves follow from the equivalence principle as ratios/differences of the two.

Value

A numeric vector of APVs (one per element of `x`).

References

Finan, M. B. (2014). *A Reading of the Theory of Life Contingency Models: A Preparation for Exam MLC/3L*, Sections 68-69.

Examples

```
# Finan (2014), Example 69.1: 3-year term on (16), i = 10%
myTable <- data.frame(x = 16:18, lx = c(20000, 17600, 14520),
                      da = c(1300, 1870, 2380), doc = c(1100, 1210, 1331))
myMdt <- new("mdt", table = myTable, name = "Finan 69.1")
A <- Axn.mdt(myMdt, x = 16, n = 3, i = 0.10, decrement = "doc")
a <- axn.mdt(myMdt, x = 16, n = 3, i = 0.10)
20000 * A / a   # level annual premium: 1250

# Finan (2014), Example 68.1: benefit 1 for cause 1, 2 for cause 2
t681 <- data.frame(x = 50:51, lx = c(1200, 800),
                   d1 = c(100, 200), d2 = c(300, 300))
m681 <- new("mdt", table = t681)
Axn.mdt(m681, x = 50, n = 2, i = 0.5, decrement = c("d1", "d2"),
        benefits = c(1, 2))  # 0.6852
```

`axyn` *Functions to evaluate life insurance and annuities on two heads.*

Description

These functions evaluates life insurances and annuities on two heads.

Usage

```
axyn(tablex, tabley, x, y, n, i, m, k = 1, status = "joint", type = "EV",
payment="advance")
Axyn(tablex, x, tabley, y, n, i, m, k = 1, status = "joint", type = "EV")
```

Arguments

tablex	Life X lifetable object.
tabley	Life Y lifetable object.
x	Age of life X.
y	Age of life Y.
n	Insured duration. Infinity if missing.
i	Interest rate. Default value is those implied in actuarialtable.
m	Deferring period. Default value is zero.
k	Fractional payments or periods where insurance is payable.
status	Either "joint" for the joint-life status model or "last" for the last-survivor status model (can be abbreviated).
type	A string, either "EV" for expected value of the actuarial present value (default) or "ST" for one stochastic realization of the underlying present value of benefits. Alternatively, one can use "expected" or "stochastic" respectively (can be abbreviated).
payment	The Payment type, either "advance" for the annuity due (default) or "arrears" for the annuity immediate. Alternatively, one can use "due" or "immediate" respectively (can be abbreviated).

Details

Actuarial mathematics book formulas has been implemented.

Value

A numeric value returning APV of chosen insurance form.

Warning

The function is provided as is, without any warranty regarding the accuracy of calculations. The author disclaims any liability for eventual losses arising from direct or indirect use of this software.

Note

Deprecated functions. Use Axyzn and axyzn instead.

Author(s)

Giorgio A. Spedicato

References

Actuarial Mathematics (Second Edition), 1997, by Bowers, N.L., Gerber, H.U., Hickman, J.C., Jones, D.A. and Nesbitt, C.J.

See Also

pxyt

Examples

```
## Not run:
 data(soa08Act)
 #last survival status annuity
 axyn(tablex=soa08Act, tabley=soa08Act, x=65, y=70,
  n=5,  status = "last",type = "EV")
    #first survival status annuity
 Axyn(tablex=soa08Act, tabley=soa08Act, x=65, y=70,
 status = "last",type = "EV")

## End(Not run)
```

Axyzn *Multiple lifes insurances and annuities*

Description

Function to evalate the multiple lives insurances and annuities

Usage

```
Axyzn(tablesList, x, n, i, m, k = 1, status = "joint", type = "EV",
power=1)
axyzn(tablesList, x, n, i, m, k = 1, status = "joint", type = "EV",
power=1, payment="advance")
```

Arguments

tablesList	A list whose elements are either lifetable or actuarialtable class objects.
x	A vector of the same size of tableList that contains the initial ages.
n	Lenght of the insurance.
i	Interest rate
m	Deferring period.
k	Fractional payment frequency.
status	Either "joint" for the joint-life status model or "last" for the last-survivor status model (can be abbreviated).

type	A string, either "EV" for expected value of the actuarial present value (default) or "ST" for one stochastic realization of the underlying present value of benefits. Alternatively, one can use "expected" or "stochastic" respectively (can be abbreviated).
power	The power of the APV. Default is 1 (mean).
payment	The Payment type, either "advance" for the annuity due (default) or "arrears" for the annuity immediate. Alternatively, one can use "due" or "immediate" respectively (can be abbreviated).

Details

In theory, these functions apply the same concept of life insurances on one head on multiple heads.

Value

The insurance value is returned.

Note

These functions are the more general version of axyn and Axyn.

Author(s)

Giorgio Alfredo Spedicato, Kevin J. Owens.

References

Broverman, S.A., Mathematics of Investment and Credit (Fourth Edition), 2008, ACTEX Publications.

See Also

axyn,Axyn.

Examples

```
data(soaLt)
soa08Act=with(soaLt, new("actuarialtable",interest=0.06,
x=x,lx=Ix,name="SOA2008"))
#evaluate and life-long annuity for an aged 65
listOfTables=list(soa08Act, soa08Act)
#Check actuarial equality
axyzn(listOfTables,x=c(60,70),status="last")
axn(listOfTables[[1]],60)+axn(listOfTables[[2]],70)-
axyzn(listOfTables,x=c(60,70),status="joint")
```

`buildMdtFromIndependentRates` *Build an mdt object from a matrix of independent (ASDT) rates*

Description

`buildMdtFromIndependentRates` constructs a multiple-decrement table (`mdt`) from a matrix of independent single-decrement rates $q'^{(j)}_x$, the inverse of `independentRatesFromMdt`.

Usage

```
buildMdtFromIndependentRates(
  x,
  qx.primes,
  radix = 1e+05,
  name = "ASDT-built mdt"
)
```

Arguments

`x`	Integer vector of ages (must be consecutive and start at 0 after internal completion by `new("mdt", ...)`). If missing, ages `0:(nrow(qx.primes)-1)` are used.
`qx.primes`	Numeric matrix of independent rates. Rows correspond to ages in `x`, columns to decrement causes. Column names, if any, become the decrement identifiers in the resulting table; otherwise generic names `d1`, `d2`, ... are used.
`radix`	Radix (initial cohort size). Default 100 000.
`name`	Character string for the table name. Default `"ASDT-built mdt"`.

Details

For each age the combined (absolute) rate of decrement j is obtained by the UDD-based integration formula

$$q^{(j)}_x = q'^{(j)}_x \int_0^1 \prod_{i \neq j} \left(1 - s\, q'^{(i)}_x\right) ds,$$

which is the same formula used by `qxt.fromQxprime` for a single age. The resulting absolute rates are multiplied by $l^{(\tau)}_x$ to obtain the decrement counts, and the survivorship column is computed recursively from $p^{(\tau)}_x = \prod_j (1 - q'^{(j)}_x)$.

Value

An `mdt` object.

See Also

independentRatesFromMdt for the reverse extraction, qxt.fromQxprime for the single-age formula.

Examples

```
# Finan (2014) Example 67.4:
# Three decrements (death, disability, retirement) at ages 60-61.
qp <- matrix(c(0.010, 0.030, 0.100,
               0.013, 0.050, 0.200), nrow = 2, byrow = TRUE,
             dimnames = list(NULL, c("death", "disability", "retirement")))
mdt674 <- buildMdtFromIndependentRates(x = 60:61, qx.primes = qp,
                                       radix = 1000, name = "Finan 67.4")
print(mdt674)
```

---

decreasingAnnuity *Function to evaluate decreasing annuities.*

Description

This function returns present values for decreasing annuities-certain.

Usage

```
decreasingAnnuity(i, n, type = "immediate")
```

Arguments

i	A numeric value representing the interest rate.
n	The number of periods.
type	The payment type. Use "immediate" (default) for an annuity-immediate, where payments are made at the end of each period, or "due" for an annuity-due, where payments are made at the beginning of each period. For compatibility, "arrears" is an alias for "immediate" and "advance" is an alias for "due" (can be abbreviated).

Details

A decreasing annuity has the following flows of payments: n, n-1, n-2, ..., 1, 0. For an annuity-immediate these payments occur at times $1, 2, \ldots, n$; for an annuity-due they occur at times $0, 1, \ldots, n-1$.

Value

A numeric value reporting the present value of the decreasing cash flows.

Warning

The function is provided as is, without any guarantee regarding the accuracy of calculation. The author disclaims any liability for eventual losses arising from direct or indirect use of this software.

Note

This function calls `presentValue` function internally.

Author(s)

Giorgio A. Spedicato

References

Broverman, S.A., Mathematics of Investment and Credit (Fourth Edition), 2008, ACTEX Publications.

See Also

`annuity`, `increasingAnnuity`, `DAxn`

Examples

```
# The present value of 10, 9, 8, ..., 0 payable at the end of the period for 10 years is
decreasingAnnuity(i = 0.03, n = 10)
# Assuming a 3% interest rate
sum((10:1)/(1 + .03)^(1:10))
```

---

demoCanada *Canada Mortality Rates for UP94 Series*

Description

UP94 life tables underlying mortality rates

Usage

```
data(demoCanada)
```

Format

A data frame with 120 observations on the following 7 variables.

`x` age

`up94M` UP 94, males

`up94F` UP 94, females

`up942015M` UP 94 projected to 2015, males

up942015f UP 94 projected to 2015, females

up942020M UP 94 projected to 2020, males

up942020F UP 94 projected to 2020, females

Details

Mortality rates are provided.

Source

Courtesy of Andrew Botros

References

Courtesy of Andrew Botros

Examples

```
data(demoCanada)
head(demoCanada)
#create the up94M life table
up94MLt<-probs2lifetable(probs=demoCanada$up94M,radix=100000,"qx",name="UP94")
#create the up94M actuarial table table
up94MAct<-new("actuarialtable", lx=up94MLt@lx, x=up94MLt@x,interest=0.02)
```

---

demoChina *China Mortality Rates for life table construction*

Description

Seven yearly mortality rates for each age

Usage

```
data(demoChina)
```

Format

A data frame with 106 observations on the following 8 variables.

age Attained age

CL1 CL1 rates

CL2 CL2 rates

CL3 CL3 rates

CL4 CL4 rates

CL5 CL5 rates

CL6 CL6 rates

CL90-93 CL 90-93 rates

Details

See the source link for details.

Source

Society of Actuaries

References

https://mort.soa.org/

Examples

```
data(demoChina)
tableChinaCL1<-probs2lifetable(probs=demoChina$CL1,radix=1000,type="qx",name="CHINA CL1")
```

---

demoFrance *French population life tables*

Description

Illustrative life tables from French population.

Usage

```
data(demoFrance)
```

Format

A data frame with 113 observations on the following 5 variables.

`age` Attained age

`TH00_02` Male 2000 life table

`TF00_02` Female 2000 life table

`TD88_90` 1988 1990 life table

`TV88_90` 1988 1990 life table

Details

These tables are real French population life tables. They regard 88 - 90 and 00 - 02 experience.

Source

Actuaris - Winter Associes

Examples

```
data(demoFrance)
head(demoFrance)
```

demoGermany *German population life tables*

Description

Dataset containing mortality rates for German population, male and females.

Usage

```
data(demoGermany)
```

Format

A data frame with 113 observations on the following 5 variables.

`x` Attained age

`qxMale` Male mortality rate

`qxFemale` Female mortality rate

Details

Sterbetafel DAV 1994

Source

Private communicatiom

Examples

```
data(demoGermany)
head(demoGermany)
```

demoIta *Italian population life tables for males and females*

Description

This dataset reports five pairs of Italian population life tables. These table can be used to create life table objects and actuarial tables object.

Usage

```
data(demoIta)
```

Format

A data frame with 121 observations on the following 9 variables.

`X` a numeric vector, representing ages from 0 to ω.

`SIM02` a numeric vector, 2002 cross section general population males life table

`SIF02` a numeric vector, 2002 cross section general population females life table

`SIM00` a numeric vector, 2000 cross section general population males life table

`SIF00` a numeric vector, 2000 cross section general population females life table

`SIM92` a numeric vector, 1992 cross section general population males life table

`SIF92` a numeric vector, 1992 cross section general population females life table

`SIM81` a numeric vector, 1981 cross sectional general population males life table

`SIF81` a numeric vector, 1981 cross sectional general population females life table

`SIM61` a numeric vector, 1961 cross sectional general population males life table

`SIF61` a numeric vector, 1961 cross sectional general population females life table

`RG48M` a numeric vector, RG48 projected males life table

`RG48F` a numeric vector, RG48 projected females life table

`IPS55M` a numeric vector, IPS55 projected males life table

`IPS55F` a numeric vector, IPS55 projected females life table

`SIM71` a numeric vector, 1971 cross sectional general population males life table

`SIM51` a numeric vector, 1951 cross sectional general population males life table

`SIM31` a numeric vector, 1931 cross sectional general population males life table

Details

These table contains the vectors of survival at the beginning of life years and are the building block of both `lifetable` and `actuarialtable` classes.

Source

These tables comes from Italian national statistical bureau (ISTAT) for SI series, government Ministry of Economics (Ragioneria Generale dello Stato) for RG48 or from Insurers' industrial association IPS55. RG48 represents the projected survival table for the 1948 born cohort, while IPS55 represents the projected survival table for the 1955 born cohort.

References

ISTAT, IVASS, Ordine Nazionale Attuari

Examples

```
#load and show
data(demoIta)
head(demoIta)
#create sim92 life and actuarial table
lxsim92<-demoIta$SIM92

lxsim92<-lxsim92[!is.na(lxsim92) & lxsim92!=0]
xsim92<-seq(0,length(lxsim92)-1,1)
#create the table
sim92lt=new("lifetable",x=xsim92,lx=lxsim92,name="SIM92")
plot(sim92lt)
```

---

demoJapan *Japan Mortality Rates for life table construction*

Description

Two yearly mortality rates for each age

Usage

```
data(demoJapan)
```

Format

A data frame with 110 observations on the following 3 variables.

`JP8587M` Male life table

`JP8587F` Female life table

`age` Attained age

Details

Dowloaded in 2012 from Society of Actuaries (SOA) mortality table web site

Source

SOA mortality web site

Examples

```
data(demoJapan)
head(demoJapan)
```

demoUk *UK life tables*

Description

AM and AF one year mortality rate. Series of 1992

Usage

```
data(demoUk)
```

Format

A data frame with 74 observations on the following 3 variables:

`Age` Annuitant age

`AM92` One year mortality rate (males)

`AF92` One year mortality rate (males)

Details

This data set shows the one year survival rates for males and females of the 1992 series. It has been taken from the Institute of Actuaries. The series cannot be directly used to create a life table since neither rates are not provided for ages below 16 nor for ages over 90. Various approach can be used to complete the series.

Source

Institute of Actuaries

References

https://www.actuaries.org.uk/learn-and-develop/continuous-mortality-investigation/cmi-mortality-and-morbidity-tables/92-series-tables

Examples

```
data(demoUk)
head(demoUk)
```

demoUsa *United States Social Security life tables*

Description

This data set contains period life tables for years 1990, 2000 and 2007. Both males and females life tables are reported.

Usage

```
demoUsa
```

Format

A `data.frame` containing people surviving at the beginning of "age" at 2007, 2000, and 1990 split by gender

Details

Reported age is truncated at the last age with lx>0.

Source

See https://www.ssa.gov/oact/NOTES/as120/LifeTables_Body.html

Examples

```
data(demoUsa)
head(demoUsa)
```

de_angelis_di_falco *Italian Health Insurance Data*

Description

A list of data.frames containing transition probabilities by age (row) and year of projections Transitions are split by males and females, and show probabilities of survival, death and transitions from Healty to Disabled

Usage

```
de_angelis_di_falco
```

Format

a list containing elevent items (data.frames), and an mdt data object (HealthyMaleTable2013)

Source

Paolo De Angelis, Luigi di Falco (a cura di). Assicurazioni sulla salute: caratteristiche, modelli attuariali e basi tecniche

---

`duration` *Compute the duration or the convexity of a series of CF*

Description

Compute the duration or the convexity of a series of CF

Usage

```
duration(cashFlows, timeIds, i, k = 1, macaulay = TRUE)

convexity(cashFlows, timeIds, i, k = 1)
```

Arguments

`cashFlows`	A vector representing the cash flows amounts.
`timeIds`	Cash flows times
`i`	APR interest, i.e. nominal interest rate compounded m-thly.
`k`	Compounding frequency for the nominal interest rate.
`macaulay`	Use the Macaulay formula

Details

The Macaulay duration is defined as $\sum_{t}^{T} \frac{t*CF_t\left(1+\frac{i}{k}\right)^{-t*k}}{P}$, while $\sum_{t}^{T} t*\left(t+\frac{1}{k}\right)*CF_t\left(1+\frac{y}{k}\right)^{-k*t-2}$

Value

A numeric value representing either the duration or the convexity of the cash flow series

References

Broverman, S.A., Mathematics of Investment and Credit (Fourth Edition), 2008, ACTEX Publications.

Examples

```
#evaluate the duration/convexity of a coupon payment
cf=c(10,10,10,10,10,110)
t=c(1,2,3,4,5,6)
duration(cf, t, i=0.03)
convexity(cf, t, i=0.03)
```

endowment_trio *Endowment, insurance, pure endowment, and survival annuity APVs (shared topic)*

Description

This help page groups four classical life-contingency present values:

- **Exn**: pure endowment, pays 1 at time `n` if alive.
- **Axn**: term/whole life insurance, pays 1 at death within `n` years (or up to limiting age if `n` is missing), with fractional claim timing.
- **AExn**: n-year endowment insurance, i.e. `Axn` + `Exn`.
- **axn**: survival annuity (immediate/due), with deferment `m` and `k` payments per year.

Usage

```
Exn(actuarialtable, x, n, i = actuarialtable@interest, type = "EV", power = 1)

axn(
  actuarialtable,
  x,
  n,
  i = actuarialtable@interest,
  m,
  k = 1,
  type = "EV",
  power = 1,
  payment = "advance",
  ...
)

Axn(
  actuarialtable,
  x,
  n,
  i = actuarialtable@interest,
  m,
  k = 1,
  type = "EV",
  power = 1,
  ...
)

AExn(
  actuarialtable,
  x,
```

```
  n,
  i = actuarialtable@interest,
  k = 1,
  type = "EV",
  power = 1
)
```

Arguments

actuarialtable	A lifetable or actuarialtable object.
x	Attained age at inception.
n	Contract length in years. If missing, for Exn and Axn it is set to pmax(ceiling((getOmega(actuarialtab - x - m)*k)/k, 0); for AExn it defaults to getOmega(actuarialtable) - x - 1. (See function-specific details below.)
i	Annual effective interest rate. Defaults to actuarialtable@interest.
type	Output type: "EV" (expected value, default) or "ST" (one stochastic realization via rLifeContingencies).
power	Power of the discounted payoff before expectation (default 1).
m	Deferment (years). Default 0. Vector accepted. (Axn/axn)
k	Fractional periods per year ($k \geq 1$). Default 1. Must be scalar. (Axn/axn/AExn insurance leg)
payment	Payment timing for annuities: "advance" (aka due) or "immediate" (aka arrears). (axn)
...	Extra args forwarded to mortality helpers (pxt, qxt), e.g. fractional assumptions. (Axn)

Details

Exn: $E_x^n = v^n \, {}_np_x$ with $v = (1+i)^{-1}$.

Axn: With fractional claims,

$$A_{\overline{n}|}^{(k)} = \sum_{j=1}^{nk} v^{t_j+1/k} \, {}_{t_j}p_x \; q_{x+t_j}^{(1/k)},$$

where $t_j = m + (j-1)/k$, computed via pxt(...) and qxt(..., t=1/k).

AExn: returns Axn(...) + Exn(...) with aligned arguments.

Vectorization: Exn and AExn accept vectors for x, n and i; the arguments are recycled to a common length and one value per element is returned.

axn: Survival annuity with payment timing "immediate" (arrears) or "due" (advance), deferment m and k payments per year (see function-specific parameters).

axn — Survival annuity (immediate/due), with deferment m and k fractional payments. For type="EV" the annuity is computed as

$$a_{\overline{n}|}^{(k)} = \sum_{j=1}^{nk} \frac{1}{k} \, v^{t_j} \, {}_{t_j}p_x,$$

where t_j are the payment times depending on `payment` and `m`.

Axn — Life insurance (term / whole life), fractional claim times. Vectorized in `x`, `n`, `m`. `k` must be scalar.

AExn — n-year endowment insurance, computed as `Axn + Exn`.

Value

A numeric value (or vector for vectorized inputs): the APV in expected value, or one simulated realization when `type="ST"`.

`Exn` — Pure endowment

Computes the actuarial present value (APV) of a pure endowment that pays 1 at time `n` provided survival to `x+n`.

References

Bowers, N. L., Gerber, H. U., Hickman, J. C., Jones, D. A., Nesbitt, C. J. (1997). *Actuarial Mathematics*, 2nd ed., SOA.

See Also

`Axn`, `AExn`, `axn`, `Exn`

Other life-contingency APVs: `arithmetic_variation_insurances`

Examples

```
## Common setup used in legacy docs
data(soaLt)
soa08Act <- with(soaLt, new("actuarialtable", interest=0.06, x=x, lx=Ix, name="SOA2008"))

## Exn (pure endowment)
Exn(soa08Act, x=30, n=35)

## Axn (term / whole life insurance)
# 10-year term, semiannual claims:
Axn(soa08Act, x=50, n=10, k=2)
# Whole life (n inferred), monthly:
Axn(soa08Act, x=30, k=12)

# Several ages and terms at once:
Exn(soa08Act, x=c(30,40,50), n=c(35,25,15))

## AExn = Axn + Exn  (legacy book-check)
AExn(soa08Act, x=35, n=30, i=0.06)
Exn(soa08Act, x=35, n=30, i=0.06) + Axn(soa08Act, x=35, n=30, i=0.06)
AExn(soa08Act, x=c(35,45), n=c(30,20))

## axn (survival annuity, legacy example)
# Life-long annuity for age 65:
axn(soa08Act, x=65)
```

```
## axn specific legacy examples
# Immediate (arrears) vs due (advance), quarterly, 15-year term deferred 5 years:
axn(soa08Act, x=60, n=15, m=5, k=4, payment="immediate")
axn(soa08Act, x=60, n=15, m=5, k=4, payment="due")
# Vectorization over x/n:
axn(soa08Act, x=c(60,65), n=c(10,20), k=12, payment="due")
```

---

exn *Expected residual life.*

Description

Expected future lifetime of a life aged x, either over the whole remaining lifespan or over a temporary period of n years.

Usage

```
exn(object, x, n, type = "curtate", fxt = 0.5, axOmega = 1 - fxt)
```

Arguments

object	A lifetable/actuarialtable object.
x	Attained age
n	Length (in years) of the period over which the expected lifetime is computed, i.e. a temporary expectation. Assumed omega - x + 1 (the whole remaining lifespan) whether missing.
type	Either "Tx", "complete" or "continuous" for the complete (continuous) future lifetime, "Kx" or "curtate" for the curtate future lifetime (can be abbreviated). Default is "curtate".
fxt	fraction of the year of age lived by those who die within the year, used by the "complete" branch (see Lxt and Tx). Defaults to 0.5 (uniform distribution of deaths); ignored by the "curtate" branch.
axOmega	mean number of years lived in the last, open-ended age interval, used by the "complete" branch when the period reaches the last tabulated age (see Tx). Defaults to 1 - fxt, which reproduces the historical closed-interval behaviour.

Details

For type = "curtate" the function returns the (temporary) curtate expectation of life

$$e_{x:\overline{n}|} = \sum_{k=1}^{n} {}_kp_x,$$

that is the expected number of complete future years lived by (x) within the next n years. With n missing it is the curtate expectation of life $e_x = E[K_x]$.

For `type = "complete"` the function returns the (temporary) complete expectation of life

$$\mathring{e}_{x:\overline{n}|} = \int_0^n {}_tp_x \, dt = \frac{{}_nL_x}{l_x},$$

evaluated under the uniform distribution of deaths (UDD) assumption within each year, i.e. $L_x = l_x - 0.5d_x$ (see `Lxt`). With n missing it is $\mathring{e}_x = T_x/l_x = E[T_x]$.

Under UDD the two quantities are related by $\mathring{e}_{x:\overline{n}|} = e_{x:\overline{n}|} + 0.5\,(1 - {}_np_x)$, which reduces to $\mathring{e}_x = e_x + 0.5$ when n covers the whole remaining lifespan.

The last tabulated age ω is treated as a closed interval: those alive at ω are assumed to die on average half a year later. Published tables that close the table with an open interval (e.g. $L_\omega = l_\omega/m_\omega$, as in the NCHS tables) can therefore show a slightly larger complete life expectancy.

Value

A numeric value representing the expected life span.

Author(s)

Giorgio Alfredo Spedicato

References

Actuarial Mathematics (Second Edition), 1997, by Bowers, N.L., Gerber, H.U., Hickman, J.C., Jones, D.A. and Nesbitt, C.J.

See Also

`lifetable`, `Tx`, `Lxt`

Examples

```
#loads and show
data(soa08Act)
#curtate expectation of life at birth
exn(object=soa08Act, x=0)
#complete expectation of life at birth (curtate + 0.5 under UDD)
exn(object=soa08Act, x=0,type="complete")
#temporary 20-year expectations at age 50
exn(object=soa08Act, x=50, n=20)
exn(object=soa08Act, x=50, n=20, type="complete")
```

getDecrements *Function to return the decrements defined in the mdt class*

Description

This function list the character decrements of the mdf class

Usage

```
getDecrements(object)
```

Arguments

object	A mdt class object

Details

A character vector is returned

Value

A character vector listing the decrements defined in the class

Note

To be updated

Author(s)

Giorgio Alfredo Spedicato

References

Marcel Finan A Reading of the Theory of Life Contingency Models: A Preparation for Exam MLC/3L

See Also

getOmega

Examples

```
#create a new table
tableDecr=data.frame(d1=c(150,160,160),d2=c(50,75,85))
newMdt<-new("mdt",name="testMDT",table=tableDecr)
getDecrements(newMdt)
```

`getLifecontingencyPv` *Functions to obtain the present value of a life contingency given the time to death*

Description

It returns the present value of a life contingency, specified by its APV symbol, known the time to death ob the sibjects

Usage

```
getLifecontingencyPv(deathsTimeX, lifecontingency, object, x, t, i = object@interest,
m = 0, k = 1, payment = "advance")
getLifecontingencyPvXyz(deathsTimeXyz, lifecontingency, tablesList, x, t, i, m = 0,
k = 1, status = "joint", payment = "advance")
```

Arguments

`deathsTimeX`	Time to death
`lifecontingency`	lifecontingency symbol
`object`	life table(s)
`x`	age(s) of the policyholder(s)
`t`	term of the contract
`i`	interest rate
`m`	deferrement
`k`	fractional payments
`payment`	The Payment type, either `"advance"` for the annuity due (default) or `"arrears"` for the annuity immediate. Alternatively, one can use `"due"` or `"immediate"` respectively (can be abbreviated).
`deathsTimeXyz`	matrix of death times from birth
`tablesList`	list of table of the same size of num column of deathTimeXyz.
`status`	Either `"joint"` for the joint-life status model or `"last"` for the last-survivor status model (can be abbreviated).

Details

This function is a wrapper to the many internal functions that give the PV known the age of death.

Value

A vector or matrix of size number of rows of deathTimeXyz / deathTimeXy

Warning

The function is provided as is, without any warranty regarding the accuracy of calculations. The author disclaims any liability for eventual losses arising from direct or indirect use of this software.

Note

Multiple life function needs to be tested

Author(s)

Spedicato Giorgio

References

Actuarial Mathematics (Second Edition), 1997, by Bowers, N.L., Gerber, H.U., Hickman, J.C., Jones, D.A. and Nesbitt, C.J.

See Also

rLifeContingenciesXyz, rLifeContingencies

Examples

```
#simulate the PV values for some life contingencies given some death times
data(soa08Act)
testgetLifecontingencyPvXyzAxyz<-getLifecontingencyPvXyz(deathsTimeXyz=
matrix(c(50,50,51,43,44,22,12,56,20,24,53,12),
ncol=2),
lifecontingency = "Axyz",tablesList = list(soa08Act, soa08Act), i = 0.03, t=30,x=c(40,50),
m=0, k=1,status="last")
testgetLifecontingencyPvAxn<-getLifecontingencyPv(deathsTimeX = seq(0, 110, by=1),
lifecontingency = "Axn", object=soa08Act,
  x=40,t=20, m=0, k=1)
```

---

getOmega *Function to return the terminal age of a life table.*

Description

This function returns the ω value of a life table object, that is, the last attainable age within a life table.

Usage

```
getOmega(object)
```

Arguments

object	A life table object.

Value

A numeric value representing the ω value of a life table object

Warning

The function is provided as is, without any guarantee regarding the accuracy of calculation. We disclaim any liability for eventual losses arising from direct or indirect use of this software.

Author(s)

Giorgio A. Spedicato

References

Actuarial Mathematics (Second Edition), 1997, by Bowers, N.L., Gerber, H.U., Hickman, J.C., Jones, D.A. and Nesbitt, C.J.

See Also

actuarialtable

Examples

```
#assumes SOA example life table to be load
data(soaLt)
soa08=with(soaLt, new("lifetable",
x=x,lx=Ix,name="SOA2008"))
#the last attainable age under SOA life table is
getOmega(soa08)
```

Iaxn *Increasing annuity life contingencies*

Description

This function evaluates increasing annuities

Usage

```
Iaxn(actuarialtable, x, n, i, m = 0, type = "EV", power=1)
```

Arguments

actuarialtable	An actuarialtable object.
x	The age of the insured head.
n	The duration of the insurance
i	The interest rate that overrides the one in the actuarialtable object.
m	The deferring period.
type	Yet only "EV" is implemented.
power	The power of the APV. Default is 1 (mean)

Details

This actuarial mathematics is generally exoteric. I have seen no valid example of it.

Value

The APV of the insurance

Warning

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Note

The function is provided as is, without any guarantee regarding the accuracy of calculation. We disclaim any liability for eventual losses arising from direct or indirect use of this software.

Author(s)

Giorgio A. Spedicato

References

Actuarial Mathematics (Second Edition), 1997, by Bowers, N.L., Gerber, H.U., Hickman, J.C., Jones, D.A. and Nesbitt, C.J.

See Also

axn,IAxn

Examples

```
#using SOA illustrative life tables
data(soaLt)
soa08Act=with(soaLt, new("actuarialtable",interest=0.06,
x=x,lx=Ix,name="SOA2008"))
#evaluate the value of a lifetime increasing annuity for a subject aged 80
Iaxn(actuarialtable=soa08Act, x=80, n=10)
```

`increasingAnnuity` *Increasing annuity.*

Description

This function evaluates non-stochastic increasing annuities.

Usage

```
increasingAnnuity(i, n, type = "immediate")
```

Arguments

`i`	A numeric value representing the interest rate.
`n`	The number of periods.
`type`	The payment type. Use `"immediate"` (default) for an annuity-immediate, where payments are made at the end of each period, or `"due"` for an annuity-due, where payments are made at the beginning of each period. For compatibility, `"arrears"` is an alias for `"immediate"` and `"advance"` is an alias for `"due"` (can be abbreviated).

Details

An increasing annuity shows the following flow of payments: $1, 2, \ldots, n-1, n$. For an annuity-immediate these payments occur at times $1, 2, \ldots, n$; for an annuity-due they occur at times $0, 1, \ldots, n-1$.

Value

The value of the annuity.

Warning

The function is provided as is, without any guarantee regarding the accuracy of calculation. We disclaim any liability for eventual losses arising from direct or indirect use of this software.

Note

This function calls internally `presentValue` function.

Author(s)

Giorgio A. Spedicato

References

Broverman, S.A., Mathematics of Investment and Credit (Fourth Edition), 2008, ACTEX Publications.

See Also

decreasingAnnuity, IAxn

Examples

```
# The present value of an increasing sequence of payments payable at the end
# of each period for 10 periods is
increasingAnnuity(i = 0.03, n = 10)
# Assuming a 3% interest rate
```

`independentRatesFromMdt` *Extract the full Associated Single Decrement Table (ASDT) from an mdt object*

Description

`independentRatesFromMdt` returns a matrix of ASDT independent rates $q_x'^{(j)}$ for every combination of age and decrement in the supplied multiple-decrement table.

Usage

```
independentRatesFromMdt(object, x, t = 1)
```

Arguments

`object`	An `mdt` object.
`x`	Optional numeric vector of ages to include. Defaults to all ages tabulated in `object` except the last. Note that this includes the synthetic ages that `new("mdt", ...)` adds below the lowest age supplied (e.g. ages 0-49 for a table given from age 50), whose decrements are all attributed to the first cause: pass `x` explicitly to restrict the result to the ages actually supplied.
`t`	Period (default 1).

Details

The independent rate for decrement j at age x is obtained under the Uniform Distribution of Deaths (UDD) assumption as

$$q_x'^{(j)} = 1 - \left(1 - q_x^{(\tau)}\right)^{q_x^{(j)}/q_x^{(\tau)}},$$

which is the same formula used by `qxt.prime.fromMdt` for a single age/decrement pair. `independentRatesFromMdt` is a convenience wrapper that applies this extraction to all ages and all decrements at once, returning the result as a tidy matrix.

Value

A numeric matrix with one row per age and one column per decrement. Row names are the ages, column names the decrement identifiers.

See Also

qxt.prime.fromMdt for a single age/decrement pair, buildMdtFromIndependentRates for the inverse operation.

Examples

```
valdezDf <- data.frame(
  x = 50:54,
  lx = c(4832555, 4821937, 4810206, 4797185, 4782737),
  heart = c(5168, 5363, 5618, 5929, 6277),
  accidents = c(1157, 1206, 1443, 1679, 2152),
  other = c(4293, 5162, 5960, 6840, 7631))
valdezMdt <- new("mdt", name = "ValdezExample", table = valdezDf)

# ASDT matrix on the ages actually supplied
independentRatesFromMdt(valdezMdt, x = 50:54)

# Subset of ages
independentRatesFromMdt(valdezMdt, x = 50:52)
```

---

intensity2Interest *Functions to switch from interest to intensity and vice versa.*

Description

There functions switch from interest to intensity and vice - versa.

Usage

```
intensity2Interest(intensity)

interest2Intensity(i)
```

Arguments

intensity	Intensity rate
i	interest rate

Details

Simple financial mathematics formulas are applied.

Value

A numeric value.

Author(s)

Giorgio A. Spedicato

References

Broverman, S.A., Mathematics of Investment and Credit (Fourth Edition), 2008, ACTEX Publications.

See Also

real2Nominal, nominal2Real

Examples

```
# a force of interest of 0.02 corresponds to an APR of
intensity2Interest(intensity=0.02)
#an interest rate equal to 0.02 corresponds to a force of interest of of
interest2Intensity(i=0.02)
```

---

interest2Discount *Functions to switch from interest to discount rates*

Description

These functions switch from interest to discount rates and vice - versa

Usage

```
interest2Discount(i)

discount2Interest(d)
```

Arguments

i	Interest rate
d	Discount rate

Details

The following formula (and its inverse) rules the relationships:

$$\frac{i}{1+i} = d$$

Value

A numeric value

Author(s)

Giorgio Alfredo Spedicato

References

Broverman, S.A., Mathematics of Investment and Credit (Fourth Edition), 2008, ACTEX Publications.

See Also

intensity2Interest,nominal2Real

Examples

```
discount2Interest(d=0.04)
```

Isn *Function to calculated accumulated increasing annuity future value.*

Description

This function evaluates non - stochastic increasing annuities future values.

Usage

```
Isn(i, n, type = "immediate")
```

Arguments

i	Interest rate.
n	Terms.
type	Either "due" for annuity due or "immediate" for annuity immediate.

Details

It calls increasingAnnuity after having capitalized by $(1+i)^n$

Value

A numeric value

Warning

The function is provided as is, without any guarantee regarding the accuracy of calculation. We disclaim any liability for eventual losses arising from direct or indirect use of this software.

Note

This function calls internally `increasingAnnuity` function.

Author(s)

Giorgio A. Spedicato

References

Broverman, S.A., Mathematics of Investment and Credit (Fourth Edition), 2008, ACTEX Publications.

See Also

`accumulatedValue`

Examples

```
Isn(n=10,i=0.03)
```

---

lifetable-class *Class* "lifetable"

Description

`lifetable` objects allow to define and use life tables with the aim to evaluate survival probabilities and mortality rates easily. Such values represent the building blocks used to estimate life insurances actuarial mathematics.

Objects from the Class

Objects can be created by calls of the form `new("lifetable", ...)`. Two vectors are needed. The age vector and the population at risk vector.

Slots

x: Object of class "numeric", representing the sequence 0,1,. . . , ω

lx: Object of class "numeric", representing the number of lives at the beginning of age x. It is a non increasing sequence. The last element of vector x is supposed to be > 0.

name: Object of class "character", reporting the name of the table

Methods

coerce `signature(from = "lifetable", to = "data.frame")`: method to create a data - frame from a lifetable object

coerce `signature(from = "lifetable", to = "markovchainList")`: coerce method from `lifetable` to `markovchainList`; available only when the optional **markovchain** package is installed

coerce `signature(from = "lifetable", to = "numeric")`: brings to numeric

coerce `signature(from = "data.frame", to = "lifetable")`: brings to life table

getOmega `signature(object = "lifetable")`: returns the maximum attainable life age

plot `signature(x = "lifetable")`: plot method

head `signature(x = "lifetable")`: head method

print `signature(x = "lifetable")`: method to print the survival probability implied in the table

show `signature(object = "lifetable")`: identical to `plot` method

summary `signature(object = "lifetable")`: it returns summary information about the object

Warning

The function is provided as is, without any warranty regarding the accuracy of calculations. The author disclaims any liability for eventual losses arising from direct or indirect use of this software.

Note

`t` may be missing in `pxt`, `qxt`, `ext`. It assumes value equal to 1 in such case.

Author(s)

Giorgio A. Spedicato

References

Actuarial Mathematics (Second Edition), 1997, by Bowers, N.L., Gerber, H.U., Hickman, J.C., Jones, D.A. and Nesbitt, C.J.

See Also

`actuarialtable`

Examples

```
showClass("lifetable")
data(soa08)
summary(soa08)
#the last attainable age under SOA life table is
getOmega(soa08)
#head and tail
data(soaLt)
tail(soaLt)
head(soaLt)
```

`Lxt` *Various demographic functions*

Description

Various demographic functions

Usage

```
Lxt(object, x, t = 1, fxt = 0.5)

Tx(object, x, fxt = 0.5, axOmega = 1 - fxt)
```

Arguments

`object`	a `lifetable` or `actuarialtable` object
`x`	age of the subject
`t`	duration of the calculation
`fxt`	fraction of the year of age lived by those who die within the year (so that $L_x = l_x - fxt\, d_x$, matching `Lxt`). Defaults to `0.5` (uniform distribution of deaths).
`axOmega`	mean number of years lived in the last, open-ended age interval by those still alive at the last tabulated age ω (so that $L_\omega = axOmega \cdot l_\omega$). The default, `1 - fxt`, reproduces the historical behaviour of the function (the last interval is closed assuming survivors live on average half a year longer when `fxt = 0.5`). Published life tables that leave the last interval open set $L_\omega = l_\omega / m_\omega$: pass `axOmega = 1 / mOmega` to reproduce them. Only relevant when $l_\omega > 0$.

Details

`Tx` il the sum of years lived since age `x` by the population of the life table, it is the sum of `Lx`. The function is provided as is, without any warranty regarding the accuracy of calculations. Use at own risk.

Value

A numeric value

Author(s)

Giorgio Alfredo Spedicato.

References

Actuarial Mathematics (Second Edition), 1997, by Bowers, N.L., Gerber, H.U., Hickman, J.C., Jones, D.A. and Nesbitt, C.J.

Examples

```
data(soaLt)
soa08Act=with(soaLt, new("actuarialtable",interest=0.06,
x=x,lx=Ix,name="SOA2008"))
Lxt(soa08Act, 67,10)
#assumes SOA example life table to be load
data(soaLt)
soa08Act=with(soaLt, new("actuarialtable",interest=0.06,x=x,lx=Ix,name="SOA2008"))
Tx(soa08Act, 67)
```

---

mdt-class *Class* "mdt"

Description

A class to store multiple decrement tables

Objects from the Class

Objects can be created by calls of the form `new("mdt", name, table,bottomCompletionSurvival, ...)`. They store absolute decrements. `bottomCompletionSurvival` (default `0.99`) is the one-year survival ratio used to synthetically back-fill ages below the lowest age supplied in `table`; it does not affect rows for ages actually supplied.

Slots

`name`**:** The name of the table

`table`**:** A data frame containing at least the number of decrements

Methods

getDecrements `signature(object = "mdt")`: return the name of decrements

getOmega `signature(object = "mdt")`: maximum attainable age

initialize `signature(.Object = "mdt")`: method to initialize the class

print `signature(x = "mdt")`: tabulate absolute decrement rates

show `signature(object = "mdt")`: show rates of decrement

coerce `signature(from = "mdt", to = "markovchainList")`: coercing to `markovchainList` objects; available only when the optional **markovchain** package is installed

coerce `signature(from = "mdt", to = "data.frame")`: coercing to `data.frame`

summary `signature(object = "mdt")`: it returns summary information about the object

Note

Currently only decrements storage of the class is defined.

Author(s)

Giorgio Alfredo Spedicato

References

Marcel Finan A Reading of the Theory of Life Contingency Models: A Preparation for Exam MLC/3L

See Also

lifetable

Examples

```
#shows the class definition
showClass("mdt")
#create a new table
tableDecr=data.frame(d1=c(150,160,160),d2=c(50,75,85))
newMdt<-new("mdt",name="testMDT",table=tableDecr)
```

---

mdtToLong *Convert an mdt to long (time, status) format for survival analysis*

Description

`mdtToLong` reshapes a multiple decrement table into an aggregated long data set with one row per (exit time, cause) and a `count` column, ready for competing-risks tools such as `survival::survfit(Surv(time, status) ~ 1, weights = count)` (Aalen-Johansen cumulative incidence) or for any analysis based on `survival::Surv`.

Usage

```
mdtToLong(object, x, t, exitTime = c("end", "mid"), dropZero = TRUE)
```

Arguments

`object`	an `mdt` object.
`x`	entry age of the cohort (default: the lowest tabulated age, 0).
`t`	length of the follow-up in years (default: to the end of the table). Lives still in the table at `x + t` are right censored.
`exitTime`	where in the year of age decrements are placed: `"end"` (default, time $k+1$ for exits in year k) or `"mid"` (time $k+1/2$, consistent with UDD).
`dropZero`	logical: drop rows with zero count (default `TRUE`).

Details

With `exitTime = "end"` the Aalen-Johansen estimate of the cumulative incidence of cause j at time k computed on the weighted long data coincides with `qxt(object, x, k, decrement = j)`; see the multiple decrement vignette.

Value

A `data.frame` with columns `time` (years since age `x`), `age` (age at exit or censoring), `status` (a factor whose first level, `"censored"`, is followed by the decrement names, as expected by `survival::Surv` for multi-state data) and `count` (number of lives, possibly non-integer).

Examples

```
valdezDf <- data.frame(
  x = 50:54,
  lx = c(4832555, 4821937, 4810206, 4797185, 4782737),
  heart = c(5168, 5363, 5618, 5929, 6277),
  accidents = c(1157, 1206, 1443, 1679, 2152),
  other = c(4293, 5162, 5960, 6840, 7631))
valdezMdt <- new("mdt", name = "ValdezExample", table = valdezDf)
long <- mdtToLong(valdezMdt, x = 50, t = 5)
head(long)
if (requireNamespace("survival", quietly = TRUE)) {
  fit <- survival::survfit(survival::Surv(time, status) ~ 1,
                           data = long, weights = count)
  summary(fit, times = 1:5)$pstate
}
```

---

median *Median age at death of a life table*

Description

S4 method for the `median` generic: the median age at death implied by a `lifetable`, i.e. the age at which the survivorship column l_x has fallen to half of its value at `age` (linear interpolation on l_x).

Usage

```
## S4 method for signature 'lifetable'
median(x, na.rm = FALSE, ...)
```

Arguments

`x`	A `lifetable` or `actuarialtable` object.
`na.rm`	Unused, kept for compatibility with the generic.
`...`	Optional `age` (default: the youngest tabulated age): the median is computed for the age at death conditional on being alive at `age`.

Value

The median age at death (a numeric value).

See Also

quantile, modalAge, exn

Examples

```
data(soa08Act)
median(soa08Act)              # median age at death from birth
median(soa08Act, age = 65)    # median age at death given survival to 65
```

---

modalAge *Modal age at death of a life table*

Description

Returns the age at which the number of deaths d_x is largest, i.e. the Lexis modal age at death. (R's base mode returns the storage type of an object and cannot be used for this, so a dedicated function is provided.)

Usage

```
modalAge(object, startAge = NULL, interpolate = FALSE)
```

Arguments

object	A lifetable or actuarialtable object.
startAge	Optional lower age bound for the search. Use it (e.g. startAge = 10) to obtain the adult modal age at death, ignoring the infant-mortality peak.
interpolate	Logical. If TRUE, a continuous estimate is returned by fitting a parabola through the d_x values at the modal age and its two neighbours (requires unit age spacing and an interior mode). Default FALSE (the integer age of maximum d_x).

Details

The death counts are $d_x = l_x - l_{x+1}$; the artificial mass at the last, open age interval (all remaining survivors) is excluded from the search.

Value

The modal age at death (a numeric value).

See Also

median, quantile

Examples

```
data(soa08Act)
modalAge(soa08Act)
modalAge(soa08Act, startAge = 10, interpolate = TRUE)
```

`multiple life probabilities`

Functions to deals with multiple life models

Description

These functions evaluate multiple life survival probabilities, either for joint or last life status. Arbitrary life probabilities can be generated as well as random samples of lifes.

Usage

```
exyzt(tablesList, x, t = Inf, status = "joint",  type = "Kx", ...)

pxyzt(tablesList, x, t, status = "joint",
fractional=rep("linear", length(tablesList)), ...)

qxyzt(tablesList, x, t, status = "joint",
fractional=rep("linear",length(tablesList)), ...)
```

Arguments

`tablesList`	A list whose elements are either `lifetable` or `actuarialtable` class objects.
`x`	A vector of the same size of tableList that contains the initial ages.
`t`	The duration.
`status`	Either `"joint"` for the joint-life status model or `"last"` for the last-survivor status model (can be abbreviated).
`type`	Either `"Tx"` for continuous future lifetime, `"Kx"` for curtate future lifetime (can be abbreviated). For `"Tx"` the complete expectation is evaluated under UDD, i.e. $\sum_{k=1}^{t} {}_kp_{xyz\ldots} + 0.5(1 - {}_tp_{xyz\ldots})$.
`fractional`	Assumptions for fractional age. One of `"linear"`, `"hyperbolic"`, `"constant force"` (can be abbreviated).
`...`	Options to be passed to `pxt`.

Details

These functions extends `pxyt` family to an arbitrary number of life contingencies.

Value

An estimate of survival / death probability or expected lifetime, or a matrix of ages.

Note

The procedure is experimental.

Author(s)

Giorgio Alfredo, Spedicato

References

Broverman, S.A., Mathematics of Investment and Credit (Fourth Edition), 2008, ACTEX Publications.

See Also

pxt,exn

Examples

```
#assessment of curtate expectation of future lifetime of the joint-life status
#generate a sample of lifes
data(soaLt)
soa08Act=with(soaLt, new("actuarialtable",interest=0.06,x=x,lx=Ix,name="SOA2008"))
tables=list(males=soa08Act, females=soa08Act)
xVec=c(60,65)
test=rLifexyz(n=50000, tablesList = tables,x=xVec,type="Kx")
#check first survival status
t.test(x=apply(test,1,"min"),mu=exyzt(tablesList=tables, x=xVec,status="joint"))
#check last survival status
t.test(x=apply(test,1,"max"),mu=exyzt(tablesList=tables, x=xVec,status="last"))
```

---

mx2qx *Mortality rates to Death probabilities*

Description

Function to convert mortality rates to probabilities of death

Usage

```
mx2qx(mx, ax = 0.5)
```

Arguments

mx	mortality rates vector
ax	the average number of years lived between ages x and x +1 by individuals who die in that interval

Details

Function to convert mortality rates to probabilities of death

Value

A vector of death probabilities

See Also

`mxt`, `qxt`, `qx2mx`

Examples

```
#using some recursion
qx2mx(mx2qx(.2))
```

`mxt` *Central mortality rate*

Description

This function returns the central mortality rate demographic function.

Usage

```
mxt(object, x, t)
```

Arguments

`object`	a `lifetable` or `actuarialtable` object
`x`	subject's age
`t`	period on which the rate is evaluated

Value

A numeric value representing the central mortality rate between age x and $x + t$.

References

Actuarial Mathematics (Second Edition), 1997, by Bowers, N.L., Gerber, H.U., Hickman, J.C., Jones, D.A. and Nesbitt, C.J.

Examples

```
#assumes SOA example life table to be load
data(soaLt)
soa08Act=with(soaLt, new("actuarialtable",interest=0.06,x=x,lx=Ix,name="SOA2008"))
#compare mx and qx
mxt(soa08Act, 60,10)
qxt(soa08Act, 60,10)
```

`nominal2Real` *Functions to switch from nominal / effective / convertible rates*

Description

Functions to switch from nominal / effective / convertible rates

Usage

```
nominal2Real(i, k = 1, type = "interest")

convertible2Effective(i, k = 1, type = "interest")

real2Nominal(i, k = 1, type = "interest")

effective2Convertible(i, k = 1, type = "interest")
```

Arguments

`i`	The rate to be converted.
`k`	The original / target compounding frequency.
`type`	Either "interest" (default) or "nominal".

Details

`effective2Convertible` and `convertible2Effective` wrap the other two functions.

Value

A numeric value.

Note

Convertible rates are synonims of nominal rates

References

Broverman, S.A., Mathematics of Investment and Credit (Fourth Edition), 2008, ACTEX Publications.

See Also

real2Nominal

Examples

```
#a nominal rate of 0.12 equates an APR of
nominal2Real(i=0.12, k = 12, "interest")
```

`plot,mdt,missing-method`

Plot a multiple decrement table

Description

S4 method for the plot generic: visualises the decrement structure of an mdt object. Three views are available: a stacked-area chart of death counts $d_x^{(j)}$ (default), a stacked bar chart, or a line chart of decrement probabilities $q_x^{(j)} = d_x^{(j)}/l_x^{(\tau)}$.

Usage

```
## S4 method for signature 'mdt,missing'
plot(x, y, type = c("area", "bar", "probability"), ...)
```

Arguments

x	An mdt object.
y	Not used (kept for S4 generic compatibility).
type	Character: one of "area" (default), "bar", or "probability". "area" and "bar" show stacked decrement counts; "probability" shows decrement-specific probabilities as lines.
...	Further arguments (currently unused).

Value

A ggplot2 object (returned invisibly).

Examples

```
valdezDf <- data.frame(
  x = 50:54,
  lx = c(4832555, 4821937, 4810206, 4797185, 4782737),
  heart = c(5168, 5363, 5618, 5929, 6277),
  accidents = c(1157, 1206, 1443, 1679, 2152),
  other = c(4293, 5162, 5960, 6840, 7631))
valdezMdt <- new("mdt", name = "ValdezExample", table = valdezDf)
plot(valdezMdt)
plot(valdezMdt, type = "bar")
plot(valdezMdt, type = "probability")
```

`presentValue` *Present value of a series of cash flows*

Description

This function evaluates the present values of a series of cash flows, given occurrence time. Probabilities of occurrence can also be taken into account.

Usage

```
presentValue(cashFlows, timeIds, interestRates, probabilities, power = 1)
```

Arguments

`cashFlows`	Numeric vector of cash flows. Must be coherent with `timeIds`.
`timeIds`	Numeric vector of time points where `cashFlows` are due.
`interestRates`	A single numeric interest rate or a numeric vector of the same length as `timeIds` used to discount cash flows.
`probabilities`	Optional numeric vector of occurrence probabilities. If missing, a vector of ones (certainty) is assumed.
`power`	Numeric power applied to discount and cash flows. Defaults to 1.

Details

Present value of a series of cash flows.

Evaluate the present value (or actuarial present value when probabilities are provided) of a vector of cash flows occurring at given time instants and discounted by provided interest rates.

`probabilities` is optional; when omitted a sequence of 1's with the same length as `timeIds` is assumed. Interest rate may be a fixed number or a vector of the same size as `timeIds`. The `power` parameter is normally unused except in special actuarial evaluations.

Value

A numeric scalar representing the present value of the cash flow vector, or the actuarial present value if `probabilities` are provided.

Note

This simple function is the kernel working core of the package. Actuarial and financial mathematics ground on it.

Author(s)

Giorgio A. Spedicato

References

Broverman, S.A., Mathematics of Investment and Credit (Fourth Edition), 2008, ACTEX Publications.

Examples

```
# simple example
cf <- c(10,10,10)    # $10 payments one per year for three years
t  <- c(1,2,3)       # years
p  <- c(1,1,1)       # payments certainty
presentValue(cashFlows = cf, timeIds = t, interestRates = 0.03, probabilities = p)
```

---

probs2lifetable *Life table from probabilities*

Description

This function returns a newly created lifetable object given either survival or death (one year) probabilities)

Usage

```
probs2lifetable(probs, radix = 10000, type = "px", name = "ungiven")
```

Arguments

probs	A real valued vector representing either one year survival or death probabilities. The last value in the vector must be either 1 or 0, depending if it represents death or survival probabilities respectively.
radix	The radix of the life table.
type	Character value either "px" or "qx" indicating how probabilities must be interpreted.
name	The character value to be put in the corresponding slot of returned object.

Details

The ω value is the length of the probs vector.

Value

A lifetable object.

Warning

The function is provided as is, without any guarantee regarding the accuracy of calculation. We disclaim any liability for eventual losses arising from direct or indirect use of this software.

Note

This function allows to use mortality projection given by other softwares with the lifecontingencies package.

Author(s)

Giorgio A. Spedicato

References

Actuarial Mathematics (Second Edition), 1997, by Bowers, N.L., Gerber, H.U., Hickman, J.C., Jones, D.A. and Nesbitt, C.J.

See Also

actuarialtable

Examples

```
fakeSurvivalProbs=seq(0.9,0,by=-0.1)
newTable=probs2lifetable(fakeSurvivalProbs,type="px",name="fake")
head(newTable)
tail(newTable)
```

---

pxt *Functions to evaluate survival, death probabilities and deaths.*

Description

These functions evaluate raw survival and death probabilities between age x and x+t

Usage

```
dxt(object, x, t, decrement)
pxt(object, x, t, fractional = "linear", decrement)
qxt(object, x, t, fractional = "linear", decrement)
```

Arguments

object	A lifetable, actuarialtable or mdt object.
x	Age of life x. (can be a vector for pxt, qxt).
t	Period until which the age shall be evaluated. Default value is 1. (can be a vector for pxt, qxt).
fractional	Assumptions for fractional age. One of "linear", "hyperbolic", "constant force" (can be abbreviated).
decrement	The reason of decrement (only for mdt class objects). Can be either ordinal numbers or the names of decrements; when several are given the probability (or number) of leaving the table because of any of them is returned.

Details

Fractional assumptions are:

- linear: linear interpolation between consecutive ages, i.e. assume uniform distribution.
- constant force of mortality : constant force of mortality, also known as exponential interpolation.
- hyperbolic: Balducci assumption, also known as harmonic interpolation.

Note that `fractional="uniform"`, `"exponential"`, `"harmonic"` or `"Balducci"` is also authorized. See references for details.

`dxt`, `pxt` and `qxt` are S4 generics with methods for `lifetable` (and hence `actuarialtable`) and `mdt` objects; other packages can add methods for new table classes.

For `mdt` objects with a `decrement`, ${}_tq_x^{(j)} = {}_td_x^{(j)}/l_x^{(\tau)}$ and `pxt` returns its complement $1 - {}_tq_x^{(j)}$; ages must be tabulated integers and fractional `t` is interpolated linearly (UDD) within the year.

Value

A numeric value representing requested probability.

Warning

The function is provided as is, without any warranty regarding the accuracy of calculations. The author disclaims any liability for eventual losses arising from direct or indirect use of this software.

Note

Function `dxt` accepts also fractional value of t. Linear interpolation is used in such case. These functions are called by many other functions.

Author(s)

Giorgio A. Spedicato

References

Actuarial Mathematics (Second Edition), 1997, by Bowers, N.L., Gerber, H.U., Hickman, J.C., Jones, D.A. and Nesbitt, C.J.

See Also

`exn`, `lifetable`

Examples

```
#dxt example
data(soa08Act)
dxt(object=soa08Act, x=90, t=2)
#qxt example
qxt(object=soa08Act, x=90, t=2)
```

```
#pxt example
pxt(object=soa08Act, x=90, t=2, "constant force" )
#MDT example (Valdez)
valdezMdt <- new("mdt", name = "ValdezExample", table = data.frame(
  x = 50:54, lx = c(4832555, 4821937, 4810206, 4797185, 4782737),
  heart = c(5168, 5363, 5618, 5929, 6277),
  accidents = c(1157, 1206, 1443, 1679, 2152),
  other = c(4293, 5162, 5960, 6840, 7631)))
qxt(valdezMdt, x = 50, t = 3, decrement = "heart")
qxt(valdezMdt, x = 50, t = 3, decrement = c("heart", "accidents"))
pxt(valdezMdt, x = 50, t = 3)
```

---

pxyt *Functions to evaluate joint survival probabilities.*

Description

These functions evaluate survival and death probabilities for two heads.

Usage

```
exyt(objectx, objecty, x, y, t, status = "joint")

pxyt(objectx, objecty, x, y, t, status = "joint")

qxyt(objectx, objecty, x, y, t,  status = "joint")
```

Arguments

objectx	lifetable for life X.
objecty	lifetable for life Y.
x	Age of life X.
y	Age of life Y.
t	Time until survival has to be evaluated.
status	Either "joint" for the joint-life status model or "last" for the last-survivor status model (can be abbreviated).

Value

A numeric value representing joint survival probability.

Warning

The function is provided as is, without any warranty regarding the accuracy of calculations. The author disclaims any liability for eventual losses arising from direct or indirect use of this software. Also it is being Deprecated and asap removed from the package.

Note

These functions are used to evaluate two or more life contingencies.

Author(s)

Giorgio A. Spedicato, Kevin J. Owens.

References

Actuarial Mathematics (Second Edition), 1997, by Bowers, N.L., Gerber, H.U., Hickman, J.C., Jones, D.A. and Nesbitt, C.J.

See Also

exyt

Examples

```
## Not run:
data(soa08Act)
pxyt(soa08Act, soa08Act, 65, 70,10)
pxyt(soa08Act, soa08Act, 65, 70,10, "last")

## End(Not run)
```

---

quantile *Quantiles of the age-at-death distribution of a life table*

Description

S4 method for the quantile generic: quantiles of the age at death implied by a lifetable, obtained by linear interpolation on the survivorship column l_x.

Usage

```
## S4 method for signature 'lifetable'
quantile(x, probs = seq(0, 1, 0.25), age = min(x@x), names = TRUE, ...)
```

Arguments

x	A lifetable or actuarialtable object.
...	Further arguments (currently unused).
probs	Numeric vector of probabilities in $[0, 1]$.
age	Youngest age to condition on (default: the youngest tabulated age). Quantiles refer to the age at death given survival to age.
names	Logical: if TRUE (default) the result is named with the probabilities, as quantile does.

Value

A numeric vector of age-at-death quantiles.

See Also

median, modalAge

Examples

```
data(soa08Act)
quantile(soa08Act)
quantile(soa08Act, probs = c(0.1, 0.9), age = 65)
```

---

qx2mx *Death Probabilities to Mortality Rates*

Description

Function to convert death probabilities to mortality rates

Usage

```
qx2mx(qx, ax = 0.5)
```

Arguments

qx	death probabilities
ax	the average number of years lived between ages x and x +1 by individuals who die in that interval

Details

Function to convert death probabilities to mortality rates

Value

A vector of mortality rates

See Also

mxt, qxt, mx2qx

Examples

```
data(soa08Act)
soa08qx<-as(soa08Act,"numeric")
soa08mx<-qx2mx(qx=soa08qx)
soa08qx2<-mx2qx(soa08mx)
```

`qxt.prime.fromMdt` *Return Associated single decrement from absolute rate of decrement*

Description

Return Associated single decrement from absolute rate of decrement

Usage

```
qxt.prime.fromMdt(object, x, t = 1, decrement)

qxt.fromQxprime(qx.prime, other.qx.prime, t = 1)
```

Arguments

`object`	a mdj object
`x`	age
`t`	period (default 1)
`decrement`	type (necessary)
`qx.prime`	single ASDT decrement of which corresponding decrement is desired
`other.qx.prime`	ASDT decrements other than `qx.prime`

Value

a single value (AST)

Functions

- `qxt.fromQxprime()`: Obtain decrement from single decrements

Examples

```
#Creating the valdez mdf

valdezDf<-data.frame(
x=c(50:54),
lx=c(4832555,4821937,4810206,4797185,4782737),
hearth=c(5168, 5363, 5618, 5929, 6277),
accidents=c(1157, 1206, 1443, 1679,2152),
other=c(4293,5162,5960,6840,7631))
valdezMdt<-new("mdt",name="ValdezExample",table=valdezDf)

qxt.prime.fromMdt(object=valdezMdt,x=53,decrement="other")

#Finan example 67.2

qxt.fromQxprime(qx.prime = 0.01,other.qx.prime = c(0.03,0.06))
```

`rLifeContingencies` *Function to generate samples from the life contingencies stochastic variables*

Description

Function to generate samples from the life contingencies stochastic variables

Usage

```
rLifeContingencies(
  n,
  lifecontingency,
  object,
  x,
  t,
  i = object@interest,
  m = 0,
  k = 1,
  parallel = FALSE,
  nthreads = NULL,
  payment = "advance"
)

rLifeContingenciesXyz(
  n,
  lifecontingency,
  tablesList,
  x,
  t,
  i,
  m = 0,
  k = 1,
  status = "joint",
  parallel = FALSE,
  nthreads = NULL,
  payment = "advance"
)
```

Arguments

`n`	Size of sample
`lifecontingency`	A character string, either `"Exn"`, `"Axn"`, `"axn"`, `"IAxn"` or `"DAxn"`
`object`	An `actuarialtable` object.
`x`	Policyholder's age at issue time; for `rLifeContingenciesXyz` a numeric vector of the same length of `object`, containing the policyholders' ages

t	The lenght of the insurance. Must be specified according to the present value of benefits definition.
i	The interest rate, whose default value is the actuarialtable interest rate slot value.
m	Deferring period, default value is zero.
k	Fractional payment, default value is 1.
parallel	Request multi-threaded (OpenMP) computation of the per-sample payoff. This is opt-in twice: it has an effect only if parallel = TRUE *and* the option options(lifecontingencies.op = TRUE) has been set by the user; otherwise the (already vectorised) sequential kernel is used. It is also a no-op when the installed binary was built without OpenMP support (see lifecontingencies:::.hasOpenMP()). Simulated lifetimes are drawn in R before the parallel region, so results are identical with and without parallelisation for a given seed.
nthreads	Number of OpenMP threads used when parallelisation is active. Defaults to NULL, which falls back to getOption("lifecontingencies.nthreads", 2L); it is never set automatically to the number of available cores.
payment	The Payment type, either "advance" for the annuity due (default) or "arrears" for the annuity immediate. Alternatively, one can use "due" or "immediate" respectively (can be abbreviated).
tablesList	A list of actuarialtable objects
status	Either "joint" for the joint-life status model or "last" for the last-survivor status model (can be abbreviated).

Value

A numeric vector

Examples

```
## Not run:
 #assumes SOA example life table to be load
 data(soaLt)
 soa08Act=with(soaLt, new("actuarialtable",interest=0.06, x=x,lx=Ix,name="SOA2008"))
 out<-rLifeContingencies(n=1000, lifecontingency="Axn",object=soa08Act, x=40,
 t=getOmega(soa08Act)-40, m=0)
 APV=Axn(soa08Act,x=40)
 #check if out distribution is unbiased
 t.test(x=out, mu=APV)$p.value>0.05

## End(Not run)
## Not run:
data(soa08Act)
n=10000
lifecontingency="Axyz"
tablesList=list(soa08Act,soa08Act)
x=c(60,60); i=0.06; m=0; status="joint"; t=30; k=1
APV=Axyzn(tablesList=tablesList,x=x,n=t,m=m,k=k,status=status,type="EV")
samples<-rLifeContingenciesXyz(n=n,lifecontingency = lifecontingency,tablesList = tablesList,
```

```
x=x,t=t,m=m,k=k,status=status, parallel=FALSE)
APV
mean(samples)

## End(Not run)
```

---

rLifes *Function to generate random future lifetimes*

Description

Function to generate random future lifetimes

Usage

```
rLife(n, object, x = 0, k = 1, type = "Tx")

rLifexyz(n, tablesList, x, k = 1, type = "Tx")
```

Arguments

n	Number of variates to generate
object	An object of class lifetable
x	The attained age of subject x, default value is 0
k	Number of periods within the year when it is possible death to happen, default value is 1
type	Either "Tx" for continuous future lifetime, "Kx" for curtate future lifetime (can be abbreviated).
tablesList	An list of lifetables

Details

Under the uniform distribution of deaths assumption the complete future lifetime is the curtate one plus an independent uniform fraction of year, $T_x = K_x + U$ with $U \sim Unif(0, 1)$, hence $E[T_x] = E[K_x] + 0.5$. For type="Tx" the function returns $K_x + 0.5/k$, i.e. a deterministic mid-period fraction, so only the expected value (not the full distribution) of T_x is reproduced.

Value

A numeric vector of n elements.

Note

The function is provided as is, without any warranty regarding the accuracy of calculations. The author disclaims any liability for eventual losses arising from direct or indirect use of this software.

References

Actuarial Mathematics (Second Edition), 1997, by Bowers, N.L., Gerber, H.U., Hickman, J.C., Jones, D.A. and Nesbitt, C.J.

See Also

lifetable, exn

Examples

```
## Not run:
##get 20000 random future lifetimes for the Soa life table at birth
data(soa08Act)
lifes=rLife(n=20000,object=soa08Act, x=0, type="Tx")
# check if the expected life at birth derived from the life table is statistically equal
# to the expected value of the sample
t.test(x=lifes, mu=exn(soa08Act, x=0, type="continuous"))

## End(Not run)
## Not run:
#assessment of curtate expectation of future lifetime of the joint-life status
#generate a sample of lifes
data(soaLt)
soa08Act=with(soaLt, new("actuarialtable",interest=0.06,x=x,lx=Ix,name="SOA2008"))
tables=list(males=soa08Act, females=soa08Act)
xVec=c(60,65)
test=rLifexyz(n=50000, tablesList = tables,x=xVec,type="Kx")
#check first survival status
t.test(x=apply(test,1,"min"),mu=exyzt(tablesList=tables, x=xVec,status="joint"))
#check last survival status
t.test(x=apply(test,1,"max"),mu=exyzt(tablesList=tables, x=xVec,status="last"))

## End(Not run)
```

---

rmdt *Simulate from a multiple decrement table*

Description

Simulate from a multiple decrement table

Usage

```
rmdt(n = 1, object, x = 0, t = 1, t0 = "alive", include.t0 = TRUE)
```

Arguments

n	Number of simulations.
object	The mdt object to simulate from.
x	the period to simulate from.
t	the period until to simulate.
t0	initial status (default is "alive").
include.t0	should initial status to be included (default is TRUE)?

Value

A matrix with n columns (the length of simulation) and either t (if initial status is not included) or t+1 rows.

Details

The function uses rmarkovchain from the optional markovchain package to simulate the chain: it stops with an informative error if that package is not installed.

Author(s)

Giorgio Alfredo Spedicato

See Also

rLifeContingenciesXyz,rLifeContingencies

Examples

```
mdtDf<-data.frame(x=c(0,1,2,3),death=c(100,50,30,10),lapse=c(150,20,2,0))
myMdt<-new("mdt",name="example Mdt",table=mdtDf)
if (requireNamespace("markovchain", quietly = TRUE)) {
  ciao<-rmdt(n=5,object = myMdt,x = 0,t = 4,include.t0=FALSE,t0="alive")
}
```

---

soa08 *Society of Actuaries Illustrative Life Table object.*

Description

This is the table that appears in the classical book Actuarial Mathematics in Appendix 2A and used throughout the book to illustrate life contingent calculations. The Society of Actuaries has been using this table when administering US actuarial professional MLC preliminary examinations.

Usage

```
data(soa08)
```

Format

Formal class 'lifetable' [package "lifecontingencies"] with 3 slots ..@ x : int [1:141] 0 1 2 3 4 5 6 7 8 9 ... ..@ lx : num [1:141] 100000 97958 97826 97707 97597 ... ..@ name: chr "SOA Illustrative Life Table"

Details

This table is a blend of Makeham's mortality law for ages 13 and above and some ad hoc values for ages 0 to 12.

The parameters for Makeham's mortality law are

1000 * mu(x) = 0.7 + 0.05 * 10^(0.04 * x)

where mu(x) is the force of mortality.

The published Illustrative Life Table just shows ages 0 to 110 but in the computing exercises of chapter 3 the authors explain that the table's age range is from 0 to 140.

Note

This table is based on US 1990 general population mortality.

References

Actuarial Mathematics (Second Edition), 1997, by Bowers, N.L., Gerber, H.U., Hickman, J.C., Jones, D.A. and Nesbitt, C.J.

Examples

```
data(soa08)
## maybe str(soa08) ; plot(soa08) ...
```

---

soa08Act *Society of Actuaries Illustrative Life Table with interest rate at 6*

Description

An object of class actuarialtable built from the SOA illustrative life table. Interest rate is 6

Usage

```
data(soa08Act)
```

Format

Formal class 'actuarialtable' [package "lifecontingencies"] with 4 slots ..@ interest: num 0.06 ..@ x : int [1:141] 0 1 2 3 4 5 6 7 8 9 ... ..@ lx : num [1:141] 100000 97958 97826 97707 97597 ... ..@ name : chr "SOA Illustrative Life Table"

Details

This table is a blend of Makeham's mortality law for ages 13 and above and some ad hoc values for ages 0 to 12.

The parameters for Makeham's mortality law are

1000 * mu(x) = 0.7 + 0.05 * 10^(0.04 * x)

where mu(x) is the force of mortality.

The published Illustrative Life Table just shows ages 0 to 110 but in the computing exercises of chapter 3 the authors explain that the table's age range is from 0 to 140.

References

Actuarial Mathematics (Second Edition), 1997, by Bowers, N.L., Gerber, H.U., Hickman, J.C., Jones, D.A. and Nesbitt, C.J.

Examples

```
## Not run:
 data(soa08Act)

## End(Not run)
```

SoAISTdata *SoA illustrative service table*

Description

Bowers' book Illustrative Service Table

Usage

```
data(SoAISTdata)
```

Format

A data frame with 41 observations on the following 6 variables.

`x` Attained age

`lx` Surviving subjects ate the beginning of each age

`death` Drop outs for death cause

`withdrawal` Drop outs for withdrawal cause

`inability` Drop outs for inability cause

`retirement` Drop outs for retirement cause

Details

It is a data frame that can be used to create a multiple decrement table

Source

Optical recognized characters from below source with some few adjustments

References

Actuarial Mathematics (Second Edition), 1997, by Bowers, N.L., Gerber, H.U., Hickman, J.C., Jones, D.A. and Nesbitt, C.J.

Examples

```
data(SoAISTdata)
head(SoAISTdata)
```

---

soaLt *Society of Actuaries life table*

Description

This table has been used by the classical book Actuarial Mathematics and by the Society of Actuaries for US professional examinations.

Usage

```
data(soaLt)
```

Format

A `data.frame` with 111 obs on the following 2 variables:

`x` a numeric vector

`Ix` a numeric vector

Details

Early ages have been found elsewere since miss in the original data sources; SOA did not provide population at risk data for certain spans of age (e.g. 1-5, 6-9, 11-14 and 16-19)

References

Actuarial Mathematics (Second Edition), 1997, by Bowers, N.L., Gerber, H.U., Hickman, J.C., Jones, D.A. and Nesbitt, C.J.

Examples

```
data(soaLt)
head(soaLt)
```

`Uk life tables` *Uk AM AF 92 life tables*

Description

Uk AM AF life tables

Usage

```
data(AF92Lt)
```

Format

The format is: Formal class 'lifetable' [package ".GlobalEnv"] with 3 slots ..@ x : int [1:111] 0 1 2 3 4 5 6 7 8 9 ... ..@ lx : num [1:111] 100000 99924 99847 99770 99692 ... ..@ name: chr "AF92"

Details

Probabilities for earliest (under 16) and lastest ages (over 92) have been derived using a Brass - Logit model fit on Society of Actuaries life table.

Source

See Uk life table.

References

https://www.actuaries.org.uk/learn-and-develop/continuous-mortality-investigation/cmi-mortality-and-morbidity-tables/92-series-tables

Examples

```
data(AF92Lt)
exn(AF92Lt)
data(AM92Lt)
exn(AM92Lt)
```

varxn *Variance and standard deviation of the future lifetime*

Description

varxn and sdxn return the variance and the standard deviation of the future lifetime of a life aged x, as the natural second-moment companions of exn (which returns the mean).

Usage

```
varxn(object, x, n, type = "Kx")

sdxn(object, x, n, type = "Kx")
```

Arguments

object	A lifetable or actuarialtable object.
x	Attained age. Defaults to 0.
n	Length (in years) of a temporary period. If missing, the whole remaining lifespan is used.
type	Either "Kx"/"curtate" for the curtate future lifetime K_x or "Tx"/"complete"/"continuous" for the complete future lifetime T_x (can be abbreviated). Default is "Kx".

Details

For the curtate future lifetime the (temporary) variance is computed exactly from the life table as

$$\mathrm{Var}(\min(K_x, n)) = \sum_{k=1}^{n} (2k-1)\, {}_kp_x - \left(\sum_{k=1}^{n} {}_kp_x \right)^2 .$$

For the complete future lifetime the variance is returned only for the whole remaining lifespan (n missing), using the uniform-distribution-of-deaths relation $\mathrm{Var}(T_x) = \mathrm{Var}(K_x) + 1/12$ (because, under UDD, $T_x = K_x + U$ with $U \sim \mathrm{Unif}(0,1)$ independent of K_x). A temporary complete variance is not provided; use type = "Kx" for a temporary period.

Value

A numeric value: the variance (varxn) or standard deviation (sdxn) of the (temporary) future lifetime.

Author(s)

Giorgio Alfredo Spedicato

References

Dickson, D.C.M., Hardy, M.R., Waters, H.R. (2013), Actuarial Mathematics for Life Contingent Risks, 2nd ed., Cambridge University Press.

See Also

exn

Examples

```
data(soa08Act)
# variance and sd of the curtate future lifetime at birth
varxn(soa08Act, x = 0)
sdxn(soa08Act, x = 0)
# complete future lifetime: Var(T) = Var(K) + 1/12
varxn(soa08Act, x = 65, type = "complete")
# temporary (20-year) curtate future lifetime at age 40
varxn(soa08Act, x = 40, n = 20)
```

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