

Package: MRHawkes (via r-universe)

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Type Package

Title Multivariate Renewal Hawkes Process

Version 1.0

Date 2018-08-15

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Description Simulate a (bivariate) multivariate renewal Hawkes (MRHawkes) self-exciting process, with given immigrant hazard rate functions and offspring density function. Calculate the likelihood of a MRHawkes process with given hazard rate functions and offspring density function for an (increasing) sequence of event times. Calculate the Rosenblatt residuals of the event times. Predict future event times based on observed event times up to a given time. For details see Stindl and Chen (2018) <doi:10.1016/j.csda.2018.01.021>.

License GPL (>= 2)

Depends IHSEP, stats

NeedsCompilation no

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MRHawkes-package	<i>Multivariate Renewal Hawkes Process</i>
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Description

Simulate the (bivariate) multivariate renewal Hawkes (MRHawkes) process with a given distribution for the two waiting times between immigrants, given offspring density functions, and also the branching ratios. Calculation of the likelihood of a MRHawkes process model with a given sequence of (distinct) event times and labels up to a censoring time. Calculate the Rosenblatt residuals of fitting an MRHawkes process model to a sequence of event times and labels. Calculate the (filtering) distribution of the index of the most recent immigrant. Predict the time of the next event since the censoring time. Predict event times from the censoring time to a future time point.

Details

The DESCRIPTION file:

```

Package:      MRHawkes
Type:        Package
Title:       Multivariate Renewal Hawkes Process
Version:     1.0
Date:       2018-08-15
Author:      Tom Stindl and Feng Chen
Maintainer:  Tom Stindl <t.stindl@unsw.edu.au>
Description: Simulate a (bivariate) multivariate renewal Hawkes (MRHawkes) self-exciting process, with given immi
License:     GPL (>=2)
Depends:     IHSEP, stats
NeedsCompilation: no
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```

Index of help topics:

```

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              model with truncated most recent immigrant
              probabilities
fivaqks      Fiji and Vanuatu Earthquake Data
mllMRH      Minus loglikelihood of an (bivariate) MRHawkes

```

	model
m11MRH1	Minus loglikelihood of an (bivariate) MRHawkes model with most recent immigrant probabilities
m11MRH2	Minus loglikelihood of an (bivariate) MRHawkes model with Rosenblatt residuals
predDen	MRHawkes (bivariate) predictive density function
simMRHawkes	Simulate an (bivariate) renewal Hawkes (MRHawkes) process
simNSMHP	Simulate a (bivariate) non-stationary multivariate Hawkes process (NSMHP)
simpred	Simulate a fitted (bivariate) MRHawkes process model
typeRes	Minus loglikelihood of an (bivariate) MRHawkes model with Universal residuals

Author(s)

Tom Stindl <t.stindl@unsw.edu.au> Feng Chen <feng.chen@unsw.edu.au>

References

- Chen, F. and Stindl, T. (2017). Direct Likelihood Evaluation for the Renewal Hawkes Process. *Journal of Computational and Graphical Statistics*.
- Stindl, T. & Chen, F. (2018). Likelihood based inference for the multivariate renewal Hawkes process. *Computational Statistics and Data Analysis*.
- Wheatley, S., Filimonov, V., and Sornette, D. (2016) The Hawkes process with renewal immigration & its estimation with an EM algorithm. *Computational Statistics and Data Analysis*. 94: 120-135.

fivaqks

Fiji and Vanuatu Earthquake Data

Description

Times and magnitudes (Richter scale) of earthquakes in the regions of Fiji and Vanuatu, for the period 1990-2015.

Usage

data(fivaqks)

Format

A data set containing 22 variables for earthquakes around Fiji and Vanuatu from 1991 to 2015.

time Time of quake

latitude Latitude of the quake

longitude Longitude of the quake

mag Magnitude of the quake

Source

United States Geological Survey (USGS)

Examples

```
data(fivaqks)
```

mllMRH

Minus loglikelihood of an (bivariate) MRHawkes model

Description

Calculates the minus loglikelihood of an (bivariate) MRHawkes model with given immigration hazard functions μ , offspring density functions h and branching ratios η for the event times and types data on the interval $[0, cens]$.

Usage

```
mllMRH(data, cens, par,
        h1.fn = function(x, p) 1 / p * exp(- x / p),
        h2.fn = function(x, p) 1 / p * exp(- x / p),
        mu1.fn = function(x, p){
          exp(dweibull(x, shape = p[1], scale = p[2], log = TRUE) -
              pweibull(x, shape = p[1], scale = p[2], lower.tail = FALSE,
                       log.p = TRUE))
        },
        mu2.fn = function(x, p){
          exp(dweibull(x, shape = p[1], scale = p[2], log = TRUE) -
              pweibull(x, shape = p[1], scale = p[2], lower.tail = FALSE,
                       log.p = TRUE))
        },
        H1.fn = function(x, p) pexp(x, rate = 1 / p),
        H2.fn = function(x, p) pexp(x, rate = 1 / p),
        Mu1.fn = function(x, p){
          - pweibull(x, shape = p[1], scale = p[2], lower.tail = FALSE,
                    log.p = TRUE)
        },
        Mu2.fn = function(x, p){
          - pweibull(x, shape = p[1], scale = p[2], lower.tail = FALSE,
                    log.p = TRUE)
        })
```

Arguments

data A two column matrix. The first column contains the event times sorted in ascending order. The second column contains the corresponding event type with the label one or two.

cens	A scalar. The censoring time.
par	A numeric vector. Contains the ten parameters of the model, in order of the immigration parameters $\mu(\cdot)$ for the two renewal distributions, the two offspring parameters $h(\cdot)$ and lastly the four branching ratios η .
h1.fn	A (vectorized) function. The offspring density function for type one events.
h2.fn	A (vectorized) function. The offspring density function for type two events.
mu1.fn	A (vectorized) function. The immigration hazard function for events of type one.
mu2.fn	A (vectorized) function. The immigration hazard function for events of type two.
H1.fn	A (vectorized) function. Its value at t gives the integral of the offspring density function from 0 to t for type one events.
H2.fn	A (vectorized) function. Its value at t gives the integral of the offspring density function from 0 to t for type two events.
Mu1.fn	A (vectorized) function. Its value at t gives the integral of the immigrant hazard function from 0 to t for type one events.
Mu2.fn	A (vectorized) function. Its value at t gives the integral of the immigrant hazard function from 0 to t for type two events.

Value

Value of the negative log-likelihood.

Author(s)

Tom Stindl <t.stindl@unsw.edu.au> Feng Chen <feng.chen@unsw.edu.au>

Examples

```
## Magnitude 5.5 or greater earthquakes over the 25 year period from
## 01/01/1991 to 31/12/2015.
data(fivaqks);
near.fiji <- grep("Fiji", fivaqks$place)
near.vanuatu <- grep("Vanuatu", fivaqks$place)
t.beg <- strptime("1991-01-01 00:00:00", "%Y-%m-%d %H:%M:%S", tz = "UTC")
t.end <- strptime("2015-12-31 23:59:59", "%Y-%m-%d %H:%M:%S", tz = "UTC")
t0 <- 0
t1 <- as.numeric(t.end - t.beg)
tms <- strptime(fivaqks$time, "%Y-%m-%dT%H:%M:%OSZ", tz = "UTC")
ts <- as.numeric(tms[-1] - t.beg)
ts <- c(as.numeric(tms[1] - t.beg)/24, ts)
ts.fi <- ts[near.fiji]; ts.fi <- ts.fi[ts.fi >= 0 & ts.fi <= t1]
ts.va <- ts[near.vanuatu]; ts.va <- ts.va[ts.va >=0 & ts.va <= t1]
ts.c <- c(ts.fi, ts.va)
z.c <- c(rep(1, times = length(ts.fi)), rep(2, times = length(ts.va)))
o <- order(ts.c)
data <- cbind(ts.c[o], z.c[o])
```

```

## calculate the minus loglikelihood of an (bivariate) MRHawkes with some
## parameters the default hazard functions and density functions are Weibull
## and exponential respectivley
mllMRH(data, cens = t1, par = c(0.488, 20.10, 0.347, 9.53, 461, 720,
                                0.472, 0.293, 0.399, -0.0774))

## calculate the MLE for the parameter assuming known parametric forms
## of the immigrant hazard function and offspring density functions.

system.time(est <- optim(c(0.488, 20.10, 0.347, 9.53, 461, 720,
                          0.472, 0.293, 0.399, -0.0774),
                        mllMRH, data = data, cens = t1,
                        control = list(maxit = 5000, trace = TRUE),
                        hessian = TRUE)
)
## point estimate by MLE
est$par
## standard error estimates:
diag(solve(est$hessian))^0.5

```

mllMRH1

Minus loglikelihood of an (bivariate) MRHawkes model with most recent immigrant probabilities

Description

Calculates the minus loglikelihood of an (bivariate) RHawkes model with given immigration hazard functions μ , common offspring density functions h and branching ratios η for event times and event types data on interval $[0, cens]$. The same as mllMRH although this version also returns the most recent immigrant probabilities at the censoring.

Usage

```

mllMRH1(data, cens, par,
        h1.fn = function(x, p) 1 / p * exp( - x / p),
        h2.fn = function(x, p) 1 / p * exp( - x / p),
        mu1.fn = function(x, p){
          exp(dweibull(x, shape = p[1], scale = p[2], log = TRUE) -
             pweibull(x, shape = p[1], scale = p[2], lower.tail = FALSE,
                      log.p = TRUE))
        },
        mu2.fn = function(x, p){
          exp(dweibull(x, shape = p[1], scale = p[2], log = TRUE) -
             pweibull(x, shape = p[1], scale = p[2], lower.tail = FALSE,
                      log.p = TRUE))
        },
        H1.fn = function(x, p) pexp(x, rate = 1 / p),
        H2.fn = function(x, p) pexp(x, rate = 1 / p),

```

```

Mu1.fn = function(x, p){
  - pweibull(x, shape = p[1], scale = p[2], lower.tail = FALSE,
            log.p = TRUE)
},
Mu2.fn = function(x, p){
  - pweibull(x, shape = p[1], scale = p[2], lower.tail = FALSE,
            log.p = TRUE)
})

```

Arguments

data	A two column matrix. The first column contains the event times sorted in ascending order. The second column contains the corresponding event type with the label one or two.
cens	A scalar. The censoring time.
par	A numeric vector. Contains the ten parameters of the model, in order of the immigration parameters $\mu(\cdot)$ for the two renewal distributions, the two offspring parameters $h(\cdot)$ and lastly the four branching ratios η .
h1.fn	A (vectorized) function. The offspring density function for type one events.
h2.fn	A (vectorized) function. The offspring density function for type two events.
mu1.fn	A (vectorized) function. The immigration hazard function for events of type one.
mu2.fn	A (vectorized) function. The immigration hazard function for events of type two.
H1.fn	A (vectorized) function. Its value at t gives the integral of the offspring density function from 0 to t for type one events.
H2.fn	A (vectorized) function. Its value at t gives the integral of the offspring density function from 0 to t for type two events.
Mu1.fn	A (vectorized) function. Its value at t gives the integral of the immigrant hazard function from 0 to t for type one events.
Mu2.fn	A (vectorized) function. Its value at t gives the integral of the immigrant hazard function from 0 to t for type two events.

Value

m11	minus log-likelihood
p	most recent immigrant probabilities at the censoring time
n	number of events

Author(s)

Tom Stindl <tom.stindl@unsw.edu.au> Feng Chen <feng.chen@unsw.edu.au>

See Also

m11MRH

Examples

```

data <- cbind(sort(runif(1000,0,1000)),
              sample(1:2, size = 1000, replace = TRUE))
tmp <- mllMRH1(data = data, cens = 1001,
              par = c(3,1.2,1/3,0.2,1,1,0.5,0.2,0.2,0.3))
## last immigrant probabilities
lip <- tmp$p
## sample last immigrant at censoring time for component one and
## component two respectively
c(sample(0:1000, 1, replace = TRUE, prob = rowSums(lip)),
  sample(0:1000, 1, replace = TRUE, prob = colSums(lip)))

```

mllMRH2	<i>Minus loglikelihood of an (bivariate) MRHawkes model with Rosenblatt residuals</i>
---------	---

Description

Calculates the minus loglikelihood of an (bivariate) RHawkes model with given immigration hazard functions μ , common offspring density functions h and branching ratios η for event times and event types data on interval $[0, cens]$. The same as mllMRH although this version also returns the Rosenblatt residuals for goodness-of-fit assessment of the event times.

Usage

```

mllMRH2(data, cens, par,
        h1.fn = function(x, p) 1 / p * exp( - x / p),
        h2.fn = function(x, p) 1 / p * exp( - x / p),
        mu1.fn = function(x, p){
          exp(dweibull(x, shape = p[1], scale = p[2], log = TRUE) -
            pweibull(x, shape = p[1], scale = p[2], lower.tail = FALSE,
                    log.p = TRUE))
        },
        mu2.fn = function(x, p){
          exp(dweibull(x, shape = p[1], scale = p[2], log = TRUE) -
            pweibull(x, shape = p[1], scale = p[2], lower.tail = FALSE,
                    log.p = TRUE))
        },
        H1.fn = function(x, p) pexp(x, rate = 1 / p),
        H2.fn = function(x, p) pexp(x, rate = 1 / p),
        Mu1.fn = function(x, p){
          - pweibull(x, shape = p[1], scale = p[2], lower.tail = FALSE,
                    log.p = TRUE)
        },
        Mu2.fn = function(x, p){
          - pweibull(x, shape = p[1], scale = p[2], lower.tail = FALSE,
                    log.p = TRUE)
        }
)

```


Arguments

data	A two column matrix. The first column contains the event times sorted in ascending order. The second column contains the corresponding event type with the label one or two.
cens	A scalar. The censoring time.
par	A numeric vector. Contains the ten parameters of the model, in order of the immigration parameters $\mu(\cdot)$ for the two renewal distributions, the two offspring parameters $h(\cdot)$ and lastly the four branching ratios η .
h1.fn	A (vectorized) function. The offspring density function for type one events.
h2.fn	A (vectorized) function. The offspring density function for type two events.
mu1.fn	A (vectorized) function. The immigration hazard function for events of type one.
mu2.fn	A (vectorized) function. The immigration hazard function for events of type two.
H1.fn	A (vectorized) function. Its value at t gives the integral of the offspring density function from 0 to t for type one events.
H2.fn	A (vectorized) function. Its value at t gives the integral of the offspring density function from 0 to t for type two events.
Mu1.fn	A (vectorized) function. Its value at t gives the integral of the immigrant hazard function from 0 to t for type one events.
Mu2.fn	A (vectorized) function. Its value at t gives the integral of the immigrant hazard function from 0 to t for type two events.

Details

Calculate the MRHawkes point process Rosenblatt residuals

Value

m11	minus log-likelihood
w	Rosenblatt residuals of observed event times

Author(s)

Tom Stindl <t.stindl@unsw.edu.au> Feng Chen <feng.chen@unsw.edu.au>

See Also

m11MRH

Examples

```
n <- 1000
data <- cbind(sort(runif(n,0,1000)),
              sample(1:2, size = n, replace = TRUE))
tmp <- m11MRH2(data = data, cens = 1001,
```

```

par = c(1,1,1,1,1,1,0.5,0.2,0.2,0.3))
pp <- ppoints(n)
par(mfrow=c(1,2))
plot(quantile(tmp$W,prob=pp),pp,type="l",
     main="Uniform QQ plot",
     xlab="Sample quantiles",ylab="Theoretical quantiles")
abline(a = 0, b = 1, col = 2)
a <- acf(tmp$W, main = "ACF Plot")
ks.test(tmp$W,"punif")
Box.test(tmp$W,lag=tail(a$lag,1))

```

predDen

MRHawkes (bivariate) predictive density function

Description

Calculates the predictive density of the next event time after the censoring time `cens` based on the observations over the interval `[0, cens]`.

Usage

```

predDen(x, data, cens, par,
       h1.fn = function(x, p) 1 / p * exp( - x / p),
       h2.fn = function(x, p) 1 / p * exp( - x / p),
       mu1.fn = function(x, p){
         exp(dweibull(x, shape = p[1], scale = p[2], log = TRUE) -
            pweibull(x, shape = p[1], scale = p[2], lower.tail = FALSE,
                    log.p = TRUE))
       },
       mu2.fn = function(x, p){
         exp(dweibull(x, shape = p[1], scale = p[2], log = TRUE) -
            pweibull(x, shape = p[1], scale = p[2], lower.tail = FALSE,
                    log.p = TRUE))
       },
       H1.fn = function(x, p) pexp(x, rate = 1 / p),
       H2.fn = function(x, p) pexp(x, rate = 1 / p),
       Mu1.fn = function(x, p){
         - pweibull(x, shape = p[1], scale = p[2], lower.tail = FALSE,
                   log.p = TRUE)
       },
       Mu2.fn = function(x, p){
         - pweibull(x, shape = p[1], scale = p[2], lower.tail = FALSE,
                   log.p = TRUE)
       })

```

Arguments

x	A scalar. The amount of time after the censoring time cens.
data	A two column matrix. The first column contains the event times sorted in ascending order. The second column contains the corresponding event type with the label one or two.
cens	A scalar. The censoring time.
par	A numeric vector containing the twelve parameters of the model, in order of the immigration parameters $\mu(\cdot)$ for the two component distributions, the four offspring parameters $h(\cdot)$ and lastly the four branching ratios η .
h1.fn	A (vectorized) function. The offspring density function for type one events.
h2.fn	A (vectorized) function. The offspring density function for type two events.
mu1.fn	A (vectorized) function. The immigration hazard function for events of type one.
mu2.fn	A (vectorized) function. The immigration hazard function for events of type two.
H1.fn	A (vectorized) function. Its value at t gives the integral of the offspring density function from 0 to t for type one events.
H2.fn	A (vectorized) function. Its value at t gives the integral of the offspring density function from 0 to t for type two events.
Mu1.fn	A (vectorized) function. Its value at t gives the integral of the immigrant hazard function from 0 to t for type one events.
Mu2.fn	A (vectorized) function. Its value at t gives the integral of the immigrant hazard function from 0 to t for type two events.

Value

The predictive density of the next event time evaluated at x.

Author(s)

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Examples

```
## Magnitude 5.5 or greater earthquakes over the 25 year period from
## 01/01/1991 to 31/12/2015.
data(fivaqks);
near.fiji <- grep("Fiji", fivaqks$place)
near.vanuatu <- grep("Vanuatu", fivaqks$place)
t.beg <- strptime("1991-01-01 00:00:00", "%Y-%m-%d %H:%M:%S", tz = "UTC")
t.end <- strptime("2015-12-31 23:59:59", "%Y-%m-%d %H:%M:%S", tz = "UTC")
t0 <- 0
t1 <- as.numeric(t.end - t.beg)
tms <- strptime(fivaqks$time, "%Y-%m-%dT%H:%M:%OSZ", tz = "UTC")
ts <- as.numeric(tms[-1] - t.beg)
ts <- c(as.numeric(tms[1] - t.beg)/24, ts)
```

```

ts.fi <- ts[near.fiji]; ts.fi <- ts.fi[ts.fi >= 0 & ts.fi <= t1]
ts.va <- ts[near.vanuatu]; ts.va <- ts.va[ts.va >=0 & ts.va <= t1]
ts.c <- c(ts.fi, ts.va)
z.c <- c(rep(1, times = length(ts.fi)), rep(2, times = length(ts.va)))
o <- order(ts.c)
data <- cbind(ts.c[o], z.c[o])
curve(predDen(x, data = data, cens = t1,
             par = c(0.488, 20.10, 0.347, 9.53, 461, 720,
                   0.472, 0.293, 0.399, -0.0774))
      ,0 ,200, col = "red", lwd = 2, ylab = "Density")

```

simMRHawkes

Simulate an (bivariate) renewal Hawkes (MRHawkes) process

Description

Simulate an (bivariate) renewal Hawkes (MRHawkes) process with given renewal immigration distribution functions μ , offspring density functions h and branching ratios η using the cascading structure of the process.

Usage

```

simMRHawkes(re.dist1 = rweibull, par.redist1 = list(shape = 3, scale = 1.2),
            re.dist2 = rweibull, par.redist2 = list(shape = 1/3, scale = 0.2),
            h1.fn = function(x, p.h1) 1/p.h1 * exp(-x/p.h1),
            h2.fn = function(x, p.h2) 1/p.h2 * exp(-x/p.h2),
            p.h1 = 1, p.h2 = 1,
            eta11 = 0.3, eta12 = 0.1, eta21 = 0.1, eta22 = 0.3, cens = 100,
            B = 10, B0 = 50,
            max.h1 = max(optimize(h1.fn, c(0, cens), maximum = TRUE, p = p.h1)$obj,
                          h1.fn(0, p.h1), h1.fn(cens, p.h1)) * 1.1,
            max.h2 = max(optimize(h2.fn, c(0, cens), maximum = TRUE, p = p.h2)$obj,
                          h2.fn(0, p.h2), h2.fn(cens, p.h2)) * 1.1)

```

Arguments

re.dist1	The renewal distribution for type one events.
re.dist2	The renewal distribution for type two events.
par.redist1	A numeric list. The parameters of the renewal distribution for type one events.
par.redist2	A numeric list. The parameters of the renewal distribution for type two events.
h1.fn	A (vectorized) function. The offspring density function for type one events.
h2.fn	A (vectorized) function. The offspring density function for type two events.
p.h1	A numeric vector. The parameters of the offspring density for type one events.
p.h2	A numeric vector. The parameters of the offspring density for type two events.

eta11	A numeric scalar. The self-exciting branching ratio for type one events.
eta12	A numeric scalar. The cross-exciting branching ratio for type one events due to the effects of a type two event.
eta21	A numeric scalar. The cross-exciting branching ratio for type two events due to the effects of a type one event.
eta22	A numeric scalar. The self-exciting branching ratio for type two events.
cens	A scalar. The censoring time.
B	A numeric scalar. Tuning parameter
B0	A numeric scalar. Tuning parameter
max.h1	A numeric scalar. The maximum value of the offspring density for type one events.
max.h2	A numeric scalar. The maximum value of the offspring density for type two events.

Details

The function works by simulating the arrival times of immigrants according to the respective renewal immigration distribution for each event type. The birth times of offspring from each immigrant are then simulated according to a non-stationary multivariate Hawkes Process (NSMHP) with appropriate baseline and excitation functions.

Value

A numeric matrix. The row column contains the event times in ascending order while the second column contains the corresponding event type.

Author(s)

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Examples

```
B <- 10; i <- 0;
data <- replicate(B,
  {cat(i<<-i+1, '\n');
  simMRHawkes(re.dist1 = rweibull,
    par.redist1 = list(shape = 3, scale = 1.2),
    re.dist2 = rweibull,
    par.redist2 = list(shape = 1 / 3, scale = 0.2),
    p.h1 = 1, p.h2 = 1,
    eta11 = 0.3, eta12 = 0.1,
    eta21 = 0.1, eta22 = 0.3,
    cens = 100)
  })
```

simNSMHP *Simulate a (bivariate) non-stationary multivariate Hawkes process (NSMHP)*

Description

Simulate a bivariate non-stationary multivariate Hawkes process (NSMHP) with given given baseline intensity functions and self-excitation functions using the cascading structure of the process.

Usage

```
simNSMHP(TT = 100,
          nu1 = function(t) 0.6*exp(-t),
          nu2 = function(t) 0.2*exp(-t),
          g11 = function(t) 0.6*exp(-t),
          g12 = function(t) 0.2*exp(-t),
          g21 = function(t) 0.1*exp(-t),
          g22 = function(t) 0.5*exp(-t))
```

Arguments

TT	A scalar. The censoring time.
nu1	Baseline intensity function for type one events.
nu2	Baseline intensity function for type two events.
g11	Self-exciting function for type one events given the parent is a type two event.
g12	Cross-exciting function for type one events given the parent is a type two event.
g21	Cross-exciting function for type two events given the parent is a type one event.
g22	Self-exciting function for type two events given the parent is a type two event.

Details

The function works by simulating generation 0 events according to independent Poisson processes with the baseline intensity functions; then keep simulating future generation events as long as the number of the previous generation events of any type is non-zero. For each event type, we simulate these events according to M independent Poisson processes with the appropriate excitation intensity. When this recursive process stops, return events of all generations with their respective type labels as the events of the NSMHP on the interval $(0, T]$.

Value

offspr1	All offspring events of type one
offspr2	All offspring events of type two

Author(s)

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Examples

```
B <- 10; i <- 0;
data <- replicate(B,
  {cat(i<<-i+1, '\n');
  simNSMHP(TT = 100)
})
```

simpred

*Simulate a fitted (bivariate) MRHawkes process model***Description**

Simulate a fitted bivariate MRHawkes process model after the censoring time `cens` to a future time point `cens.tilde` using the cascading structure of the process.

Usage

```
simpred(data, par, cens, cens.tilde,
  re.dist1 = rweibull,
  par.redist1 = list(shape = par[1], scale = par[2]),
  re.dist2 = rweibull,
  par.redist2 = list(shape = par[3], scale = par[4]),
  h1.fn = function(x, p.h1) 1 / p.h1 * exp(- x / p.h1),
  h2.fn = function(x, p.h2) 1 / p.h2 * exp(- x / p.h2),
  p.h1 = par[5], p.h2 = par[6],
  eta11 = par[7], eta12 = par[8], eta21 = par[9], eta22 = par[10],
  B = 10, B0 = 50, pnp1 = NULL,
  max.h1 = max(optimize(h1.fn, c(0, cens.tilde - cens), maximum = TRUE,
    p = p.h1)$obj, h1.fn(0, p.h1),
    h1.fn(cens.tilde - cens, p.h1)) * 1.1,
  max.h2 = max(optimize(h2.fn, c(0, cens.tilde - cens), maximum = TRUE,
    p = p.h2)$obj, h2.fn(0, p.h2),
    h2.fn(cens.tilde - cens, p.h2)) * 1.1)
```

Arguments

<code>data</code>	A two column matrix. The first column contains the event times sorted in ascending order. The second column contains the corresponding event type with the label one or two.
<code>par</code>	A numeric vector. Contains the ten parameters of the model, in order of the immigration parameters $\mu(\cdot)$ for the two renewal distributions, the two offspring parameters $h(\cdot)$ and lastly the four branching ratios η .
<code>cens</code>	A scalar. The censoring time.
<code>cens.tilde</code>	A scalar. The time that the simulation run uptil.
<code>re.dist1</code>	The renewal distribution for type one events.
<code>re.dist2</code>	The renewal distribution for type two events.

<code>par.redist1</code>	A numeric list. The parameters of the renewal distribution for type one events.
<code>par.redist2</code>	A numeric list. The parameters of the renewal distribution for type two events.
<code>h1.fn</code>	A (vectorized) function. The offspring density function for type one events.
<code>h2.fn</code>	A (vectorized) function. The offspring density function for type two events.
<code>p.h1</code>	A numeric vector. The parameters of the offspring density for type one events.
<code>p.h2</code>	A numeric vector. The parameters of the offspring density for type two events.
<code>eta11</code>	A numeric scalar. The self-exciting branching ratio for type one events.
<code>eta12</code>	A numeric scalar. The cross-exciting branching ratio for type one events due to the effects of a type two event.
<code>eta21</code>	A numeric scalar. The cross-exciting branching ratio for type two events due to the effects of a type one event.
<code>eta22</code>	A numeric scalar. The self-exciting branching ratio for type two events.
<code>B</code>	A numeric scalar. Tuning parameter
<code>B0</code>	A numeric scalar. Tuning parameter
<code>pnp1</code>	A numeric square matrix. The joint last immigrant probabilities.
<code>max.h1</code>	A numeric scalar. The maximum value of the offspring density for type one events.
<code>max.h2</code>	A numeric scalar. The maximum value of the offspring density for for type two events.

Value

A numeric matrix that contains the simulated event times from censoring time `cens` up until `cens.tilde` and the corresponding event types.

Author(s)

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Examples

```
## Magnitude 5.5 or greater earthquakes over the 25 year period from
## 01/01/1991 to 31/12/2015.
data(fivaqks);
near.fiji <- grep("Fiji", fivaqks$place)
near.vanuatu <- grep("Vanuatu", fivaqks$place)
t.beg <- strptime("1991-01-01 00:00:00", "%Y-%m-%d %H:%M:%S", tz = "UTC")
t.end <- strptime("2015-12-31 23:59:59", "%Y-%m-%d %H:%M:%S", tz = "UTC")
t0 <- 0
t1 <- as.numeric(t.end - t.beg)
tms <- strptime(fivaqks$time, "%Y-%m-%dT%H:%M:%OSZ", tz = "UTC")
ts <- as.numeric(tms[-1] - t.beg)
ts <- c(as.numeric(tms[1] - t.beg)/24, ts)
ts.fi <- ts[near.fiji]; ts.fi <- ts.fi[ts.fi >= 0 & ts.fi <= t1]
ts.va <- ts[near.vanuatu]; ts.va <- ts.va[ts.va >=0 & ts.va <= t1]
ts.c <- c(ts.fi, ts.va)
```



```

z.c <- c(rep(1, times = length(ts.fi)), rep(2, times = length(ts.va)))
o <- order(ts.c)
data <- cbind(ts.c[o], z.c[o])
# simulate future event time based on MLE fitted Rhawkes model
N <- 100; i <- 0;
data.pred <- replicate(N,
  {cat(i<<-i+1,'\n');
  simpred(data = data,
    par = c(0.488, 20.10, 0.347, 9.53,
            461, 720,
            0.472, 0.293, 0.399, -0.0774),
    cens = t1, cens.tilde = t1 + 1000)
  })

```

Tm11MRH

Minus loglikelihood of an (bivariate) MRHawkes model with truncated most recent immigrant probabilities

Description

Calculates the minus loglikelihood of an (bivariate) MRHawkes model with given immigration hazard functions μ , offspring density functions h and branching ratios η for event times and event types data on interval $[0, cens]$ with truncated most recent immigrant probabilities looking back at only the previous B event times.

Usage

```

Tm11MRH(data, cens, par, B = 25,
  h1.fn = function(x, p) 1 / p * exp( - x / p),
  h2.fn = function(x, p) 1 / p * exp( - x / p),
  mu1.fn = function(x, p){
    exp(dweibull(x, shape = p[1], scale = p[2], log = TRUE) -
      pweibull(x, shape = p[1], scale = p[2], lower.tail = FALSE,
        log.p = TRUE))
  },
  mu2.fn = function(x, p){
    exp(dweibull(x, shape = p[1], scale = p[2], log = TRUE) -
      pweibull(x, shape = p[1], scale = p[2], lower.tail = FALSE,
        log.p = TRUE))
  },
  H1.fn = function(x, p) pexp(x, rate = 1 / p),
  H2.fn = function(x, p) pexp(x, rate = 1 / p),
  Mu1.fn = function(x, p){
    - pweibull(x, shape = p[1], scale = p[2], lower.tail = FALSE,
      log.p = TRUE)
  },
  Mu2.fn = function(x, p){

```

```

- pweibull(x, shape = p[1], scale = p[2], lower.tail = FALSE,
           log.p = TRUE)
})

```

Arguments

data	A two column matrix. The first column contains the event times sorted in ascending order. The second column contains the corresponding event type with the label one or two.
cens	A scalar. The censoring time.
par	A numeric vector. Contains the ten parameters of the model, in order of the immigration parameters $\mu(\cdot)$ for the two renewal distributions, the two offspring parameters $h(\cdot)$ and lastly the four branching ratios η .
B	A scalar. The number of previous events that are considered to be possible last immigrant arrivals.
h1.fn	A (vectorized) function. The offspring density function for type one events.
h2.fn	A (vectorized) function. The offspring density function for type two events.
mu1.fn	A (vectorized) function. The immigration hazard function for events of type one.
mu2.fn	A (vectorized) function. The immigration hazard function for events of type two.
H1.fn	A (vectorized) function. Its value at t gives the integral of the offspring density function from 0 to t for type one events.
H2.fn	A (vectorized) function. Its value at t gives the integral of the offspring density function from 0 to t for type two events.
Mu1.fn	A (vectorized) function. Its value at t gives the integral of the immigrant hazard function from 0 to t for type one events.
Mu2.fn	A (vectorized) function. Its value at t gives the integral of the immigrant hazard function from 0 to t for type two events.

Value

Value of the negative log-likelihood.

Author(s)

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Examples

```

## Magnitude 5.5 or greater earthquakes over the 25 year period from
## 01/01/1991 to 31/12/2015.
data(fivaqks);
near.fiji <- grep("Fiji", fivaqks$place)
near.vanuatu <- grep("Vanuatu", fivaqks$place)
t.beg <- strptime("1991-01-01 00:00:00", "%Y-%m-%d %H:%M:%S", tz = "UTC")
t.end <- strptime("2015-12-31 23:59:59", "%Y-%m-%d %H:%M:%S", tz = "UTC")

```

```

t0 <- 0
t1 <- as.numeric(t.end - t.beg)
tms <- strptime(fivaqks$time, "%Y-%m-%dT%H:%M:%SZ", tz = "UTC")
ts <- as.numeric(tms[-1] - t.beg)
ts <- c(as.numeric(tms[1] - t.beg)/24, ts)
ts.fi <- ts[near.fiji]; ts.fi <- ts.fi[ts.fi >= 0 & ts.fi <= t1]
ts.va <- ts[near.vanuatu]; ts.va <- ts.va[ts.va >=0 & ts.va <= t1]
ts.c <- c(ts.fi, ts.va)
z.c <- c(rep(1, times = length(ts.fi)), rep(2, times = length(ts.va)))
o <- order(ts.c)
data <- cbind(ts.c[o], z.c[o])

## calculate the minus loglikelihood of an (bivariate) MRHawkes with some
## parameters the default hazard functions and density functions are Weibull
## and exponential respectivley
Tm11MRH(data, cens = t1, par = c(0.488, 20.10, 0.347, 9.53, 461, 720,
                                0.472, 0.293, 0.399, -0.0774), B = 200)

## calculate the MLE for the parameter assuming known parametric forms
## of the immigrant hazard function and offspring density functions.

system.time(est <- optim(c(0.488, 20.10, 0.347, 9.53, 461, 720,
                          0.472, 0.293, 0.399, -0.0774),
                        Tm11MRH, data = data, cens = t1, B = 200,
                        control = list(maxit = 5000, trace = TRUE),
                        hessian = TRUE)
)
## point estimate by MLE
est$par
## standard error estimates:
diag(solve(est$hessian))^0.5

```

typeRes	<i>Minus loglikelihood of an (bivariate) MRHawkes model with Universal residuals</i>
---------	--

Description

Calculates the minus loglikelihood of an (bivariate) RHawkes model with given immigration hazard functions μ , common offspring density functions h and branching ratios η for event times and event types data on interval $[0, cens]$. The same as m11MRH although this version also returns the Universal residuals for goodness-of-fit assessment of the event types.

Usage

```

typeRes(data, cens, par, U = runif(length(data[,1])),
        h1.fn = function(x, p) 1 / p * exp( - x / p),
        h2.fn = function(x, p) 1 / p * exp( - x / p),
        mu1.fn = function(x, p){

```

```

exp(dweibull(x, shape = p[1], scale = p[2], log = TRUE) -
  pweibull(x, shape = p[1], scale = p[2], lower.tail = FALSE,
    log.p = TRUE))
},
mu2.fn = function(x, p){
  exp(dweibull(x, shape = p[1], scale = p[2], log = TRUE) -
    pweibull(x, shape = p[1], scale = p[2], lower.tail = FALSE,
      log.p = TRUE))
},
H1.fn = function(x, p) pexp(x, rate = 1 / p),
H2.fn = function(x, p) pexp(x, rate = 1 / p),
Mu1.fn = function(x, p){
  - pweibull(x, shape = p[1], scale = p[2], lower.tail = FALSE,
    log.p = TRUE)
},
Mu2.fn = function(x, p){
  - pweibull(x, shape = p[1], scale = p[2], lower.tail = FALSE,
    log.p = TRUE)
})

```

Arguments

data	A two column matrix. The first column contains the event times sorted in ascending order. The second column contains the corresponding event type with the label one or two.
cens	A scalar. The censoring time.
par	A numeric vector. Contains the ten parameters of the model, in order of the immigration parameters $\mu(\cdot)$ for the two renewal distributions, the two offspring parameters $h(\cdot)$ and lastly the four branching ratios η .
U	A numeric vector. Contains auxillary uniform random variables on the unit interval.
h1.fn	A (vectorized) function. The offspring density function for type one events.
h2.fn	A (vectorized) function. The offspring density function for type two events.
mu1.fn	A (vectorized) function. The immigration hazard function for events of type one.
mu2.fn	A (vectorized) function. The immigration hazard function for events of type two.
H1.fn	A (vectorized) function. Its value at t gives the integral of the offspring density function from 0 to t for type one events.
H2.fn	A (vectorized) function. Its value at t gives the integral of the offspring density function from 0 to t for type two events.
Mu1.fn	A (vectorized) function. Its value at t gives the integral of the immigrant hazard function from 0 to t for type one events.
Mu2.fn	A (vectorized) function. Its value at t gives the integral of the immigrant hazard function from 0 to t for type two events.

Details

Calculate the MRHawkes point process Universal residuals

Value

mll	minus log-likelihood
V	Universal residuals of observed event types

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See Also

mllMRH

Examples

```
n <- 1000
data <- cbind(sort(runif(n,0,1000)),
              sample(1:2, size = n, replace = TRUE))
tmp <- typeRes(data = data, cens = 1001,
              par = c(1,1,1,1,1,1,0.5,0.2,0.2,0.3))
pp <- ppoints(n)
par(mfrow=c(1,2))
plot(quantile(tmp$V,prob=pp),pp,type="l",
     main="Uniform QQ plot",
     xlab="Sample quantiles",ylab="Theoretical quantiles")
abline(a = 0, b = 1, col = 2)
a <- acf(tmp$V, main = "ACF Plot")
ks.test(tmp$V,"punif")
Box.test(tmp$V,lag=tail(a$lag,1))
```

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