Package ‘mapfit’

March 24, 2015

Version 0.9.7
Date 2015-03-24
Title A Tool for PH/MAP Parameter Estimation
Type Package
Author Hiroyuki Okamura
Maintainer Hiroyuki Okamura <okamu@rel.hiroshima-u.ac.jp>
Description Estimation methods for phase-type
distribution (PH) and Markovian arrival process (MAP) from
empirical data (point and grouped data) and density function.
Depends methods, Matrix
Encoding UTF-8
License GPL (>= 2)
NeedsCompilation yes
Repository CRAN
Date/Publication 2015-03-24 18:15:53

R topics documented:

  mapfit-package .............................................. 2
  BCPAug89 .................................................. 3
  cf1 ....................................................... 4
  cf1-class .................................................. 5
  erhmm ...................................................... 6
  erhmm-class ............................................... 7
  herlang .................................................... 9
  herlang-class ............................................ 10
  map ......................................................... 12
  map-class ................................................. 13
  map.acf .................................................. 14
  mapfit.group ............................................. 16
  mapfit.point ............................................. 18
  ph ......................................................... 20
mapfit-package

---

**Description**

Estimation methods for phase-type distribution (PH) and Markovian arrival process (MAP) from empirical data (point and grouped data) and density function.

**Details**

<table>
<thead>
<tr>
<th>Package:</th>
<th>mapfit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type:</td>
<td>Package</td>
</tr>
<tr>
<td>Version:</td>
<td>0.9.7</td>
</tr>
<tr>
<td>Date:</td>
<td>2015-03-24</td>
</tr>
<tr>
<td>License:</td>
<td>GPL (&gt;= 2)</td>
</tr>
<tr>
<td>LazyLoad:</td>
<td>yes</td>
</tr>
</tbody>
</table>

**Author(s)**

Hiroyuki Okamura

Maintainer: Hiroyuki Okamura <okamu@rel.hiroshima-u.ac.jp>

**See Also**

`phfit.point`, `phfit.group`, `phfit.density`, `phfit.3mom`, `mapfit.point`, `mapfit.group`

**Examples**

```r
## PH fitting with grouped data
## make sample
wgroup <- hist(x=rweibull(n=100, shape=2, scale=1),
               breaks="fd", plot=FALSE)

## PH fitting for CF1
phfit.group(ph=cf1(2), counts=wgroup$counts,}
```
**Description**

The data contains packet arrivals seen on an Ethernet at the Bellcore Morristown Research and Engineering facility. Two of the traces are LAN traffic (with a small portion of transit WAN traffic), and two are WAN traffic.

The original trace BC-pAug89 began at 11:25 on August 29, 1989, and ran for about 3142.82 seconds (until 1,000,000 packets had been captured). The trace BC-pOct89 began at 11:00 on October 5, 1989, and ran for about 1759.62 seconds. These two traces captured all Ethernet packets. The number of arrivals in the original trace is one million.

To reduce the data size, we picked the interarrival time in seconds for the first 1000 arrivals.

**Usage**

BCpAug89

**Format**

BCpAug89 is a vector for the interarrival time in seconds for 1000 arrivals.
Source

The original trace data are published in http://ita.ee.lbl.gov/html/contrib/BC.html.

---

**cf1**

*Canonical Form 1 for Phase-Type (PH) Distribution*

---

**Description**

A function to generate an object of `cf1`.

**Usage**

```r
cf1(size, alpha, rate, class = "CsparseMatrix")
```

**Arguments**

- `size`  a value for the number of phases.
- `alpha` a vector for the initial probabilities of PH distribution.
- `rate`  a vector for transition rates to next phase (diagonal elements of Q).
- `class` name of Matrix class for Q.

**Details**

The PH distribution with parameters $\alpha$, $Q$ and $\xi = -Q1$: Cumulative probability function;

$$F(q) = 1 - \alpha \exp(Qq)1$$

Probability density function;

$$f(x) = \alpha \exp(Qx)\xi,$$

where $Q$ is a bidiagonal matrix whose entries are sorted.

**Value**

`cf1` gives an object of canonical form 1 that is a subclass of PH distribution.

**Note**

`rph` is a generic function and is specified for `cf1`.

**See Also**

`ph`, `herlang`
Examples

```r
## create a CF1 with 5 phases
(param1 <- cf1(5))

## create a CF1 with 5 phases
(param1 <- cf1(size=5))

## create a CF1 with specific parameters
(param2 <- cf1(alpha=c(1,0,0), rate=c(1.0,2.0,3.0)))

## p.d.f. for 0, 0.1, ..., 1
(dph(x=seq(0, 1, 0.1), ph=param2))

## c.d.f. for 0, 0.1, ..., 1
(pph(q=seq(0, 1, 0.1), ph=param2))

## generate 10 samples (this is quicker than rph with general ph)
(rph(n=10, ph=param2))
```

---

**cf1-class**

*Class of canonical form 1 (PH distribution)*

---

**Description**

Parameters for a canonical form 1 which is a subclass of PH. This is extended from *ph*.

**Objects from the Class**

Objects are usually created by a *cf1*.

**Slots**

rate: transition rates to the next phase.

The following slots are inherited from *ph*:

size: the number of phases (transient states).

alpha: a probability (row) vector to decide an initial phase.

Q: a square matrix that means transition rates between phases.

xi: a column vector for exiting rates from phases to an absorbing state.

df: the number of free parameters.

**Methods**

*ph.moment* signature(ph = "cf1"): ...
See Also

Classes `ph` and `herlang`.

Examples

```r
## create a CF1 with 5 phases
(param1 <- cf1(5))

## create a CF1 with 5 phases
(param1 <- cf1(size=5))

## create a CF1 with specific parameters
(param2 <- cf1(alpha=c(1,0,0), rate=c(1.0,2.0,3.0)))

## p.d.f. for 0, 0.1, ..., 1
(dph(x=seq(0, 1, 0.1), ph=param2))

## c.d.f. for 0, 0.1, ..., 1
(pph(q=seq(0, 1, 0.1), ph=param2))

## generate 10 samples (this is quicker than rph with general ph)
(rph(n=10, ph=param2))
```

---

**erhmm**  

**ER-HMM (HMM with Erlang outputs)**

**Description**

A function to generate an object of `erhmm`.

**Usage**

`erhmm(shape, alpha, rate, P, class = "CsparseMatrix")`

**Arguments**

- `shape`  
  an integer vector of shape parameters of Erlang outputs.

- `alpha`  
  a vector for initial probabilities of HMM states.

- `rate`  
  a vector of rate parameters of Erlang outputs.

- `P`  
  an object of Matrix class for a transition probability matrix of HMM.

- `class`  
  name of Matrix class for `P`.

**Details**

ER-HMM has parameters `alpha`, `shape`, `rate` and `P`. HMM state changes according to a discrete-time Markov chain with transition matrix `P`. At each HMM state, there is an inherent Erlang distribution as an output. This model can be converted to a MAP.
Value

erhmm gives an object of ER-HMM.

Note

erhmm requires shape parameters. Other parameters have default values.

See Also

map, gmmpp, map.mmoment, map.jmoment, map.acf

Examples

```r
## create an ER-HMM consisting of two Erlang components with
## shape parameters 2 and 3.
erhmm(c(2,3))

## create an ER-HMM consisting of two Erlang components with
## shape parameters 2 and 3.
erhmm(shape=c(2,3))

## create an ER-HMM with specific parameters
(param <- erhmm(shape=c(2,3), alpha=c(0.3,0.7),
               rate=c(1,0,10,0),
               P=rbind(c(0.3, 0.7), c(0.1, 0.9)))))

## convert to a general MAP
as(param, "map")

## marginal moments of MAP
map.mmoment(k=3, map=as(param, "map"))

## joint moments of MAP
map.jmoment(lag=1, map=as(param, "map"))

## k-lag correlation
map.acf(map=as(param, "map"))
```
Slots

size: the number of HMM states.
alpha: a vector of initial probabilities for HMM states.
shape: shape parameters for Erlang distributions. The sum of shape parameters is the number of phases of MAP.
rate: rate parameters for Erlang distributions.
P: an object of Matrix class for a transition probability matrix of HMM.

Note

This class can be converted to map.

See Also

Classes map and gmmpp.

Examples

```r
## create an ER-HMM consisting of two Erlang components with
## shape parameters 2 and 3.
erhmm(c(2,3))

## create an ER-HMM consisting of two Erlang components with
## shape parameters 2 and 3.
erhmm(shape=c(2,3))

## create an ER-HMM with specific parameters
(param <- erhmm(shape=c(2,3), alpha=c(0.3,0.7),
              rate=c(1.0,10.0),
              P=rbind(c(0.3, 0.7), c(0.1, 0.9))))

## convert to a general MAP
as(param, "map")

## marginal moments of MAP
map.moment(k=3, map=as(param, "map"))

## joint moments of MAP
map.moment(lag=1, map=as(param, "map"))

## k-lag correlation
map.acf(map=as(param, "map"))
```
**hyperlang**

**Hyper-Erlang Distribution**

**Description**

Density function, distribution function and random generation for the hyper-Erlang distribution, and a function to generate an object of `herlang`.

**Usage**

```
herlang(shape, mixrate = rep(1/length(shape), length(shape)),
        rate = rep(1, length(shape)))
dherlang(x, herlang = herlang(shape = c(1)), log = FALSE)
pherlang(q, herlang = herlang(shape = c(1)), lower.tail = TRUE, log.p = FALSE)
rherlang(n, herlang = herlang(shape = c(1)))
```

**Arguments**

- **shape**: an integer vector of shape parameters of Erlang components.
- **mixrate**: a vector for the initial probabilities of hyper-Erlang distribution.
- **rate**: a vector of rate parameters of Erlang components.
- **x, q**: vectors of quantiles.
- **p**: a vector of probabilities.
- **n**: number of observations.
- **herlang**: an object of S4 class of hyper Erlang (`herlang`).
- **log**: logical; if TRUE, the log density is returned.
- **lower.tail**: logical; if TRUE, probabilities are \( P[X \leq x] \), otherwise, \( P[X > x] \).
- **log.p**: logical; if TRUE, the log probability is returned.

**Details**

The hyper-Erlang distribution with parameters \( m_i \) (mixrate), \( s_i \) (shape) and \( r_i \) (rate): Cumulative probability function;

\[
F(q) = \sum_i \int_0^q m_i r_i^{s_i} x^{s_i-1} e^{-r_i x} (s_i - 1)! dx
\]

Probability density function;

\[
f(x) = \sum_i m_i r_i^{s_i} x^{s_i-1} e^{-r_i x} (s_i - 1)!
\]

**Value**

`herlang` gives an object of hyper-Erlang distribution. `dherlang` gives the density function, `pherlang` gives the distribution function, and `rherlang` generates random samples.
Note

herlang requires shape parameters.

See Also

ph, herlang

Examples

```r
## create a hyper Erlang consisting of two Erlang
## with shape parameters 2 and 3.
(param1 <- herlang(c(2,3)))

## create a hyper Erlang consisting of two Erlang
## with shape parameters 2 and 3.
(param1 <- herlang(shape=c(2,3)))

## create a hyper Erlang with specific parameters
(param2 <- herlang(shape=c(2,3), mixrate=c(0.3,0.7),
                   rate=c(1.8,10.0)))

## convert to a general PH
as(param2, "ph")

## p.d.f. for 0, 0.1, ..., 1
(dherlang(x=seq(0, 1, 0.1), herlang=param2))

## c.d.f. for 0, 0.1, ..., 1
(pherlang(q=seq(0, 1, 0.1), herlang=param2))

## generate 10 samples
(rherlang(n=10, herlang=param2))
```

---

**herlang-class**

*Class of hyper Erlang*

### Description

Parameters for a hyper Erlang.

### Objects from the Class

Objects are usually created by a herlang.
Slots

- **size**: the number of components (hyper Erlang components).
- **mixrate**: a vector of mixed rates (probability for selecting a component).
- **shape**: shape parameters for Erlang distributions.
- **rate**: rate parameters for Erlang distributions.

Methods

```r
ph.moment signature(ph = "herlang"): ...
```

Note

This class can be converted to `ph`.

See Also

Classes `ph` and `cf1`.

Examples

```r
# create a hyper Erlang consisting of two Erlang
# with shape parameters 2 and 3.
(param1 <- herlang(c(2, 3)))

# create a hyper Erlang consisting of two Erlang
# with shape parameters 2 and 3.
(param1 <- herlang(shape=c(2, 3)))

# create a hyper Erlang with specific parameters
(param2 <- herlang(shape=c(2, 3), mixrate=c(0.3, 0.7),
                   rate=c(1.0, 10.0)))

# convert to a general PH
as(param2, "ph")

# p.d.f. for 0, 0.1, ..., 1
(dherlang(x=seq(0, 1, 0.1), herlang=param2))

# c.d.f. for 0, 0.1, ..., 1
(pherlang(q=seq(0, 1, 0.1), herlang=param2))

# generate 10 samples
(rherlang(n=10, herlang=param2))
```
Description

Functions to generate an object of map.

Usage

map(size, alpha, D0, D1, class = "CsparseMatrix")  
mmpp(size, class = "CsparseMatrix")  
gmmp(size, alpha, D0, D1, class = "dgeMatrix")

Arguments

size an integer for the number of phases.  
alpha a vector of probabilities for determining an initial phase.  
D0 an object of Matrix class for the infinitesimal generator without arrivals.  
D1 an object of Matrix class for the infinitesimal generator with arrivals.  
class name of Matrix class for D0 and D1.

Details

MAP parameters are alpha, D0 and D1. alpha is the probability vector to determine an initial phase at time 0. D0 is an infinitesimal generator of underlying continuous-time Markov chain (CTMC) without arrival. D1 is an infinitesimal generator of CTMC with arrival. The infinitesimal generator of underlying CTMC becomes D0 + D1. In the stationary case, alpha is often given by a stationary vector satisfying alpha(D0 + D1) = alpha.

mmpp generates an object of a specific MAP called MMPP. MMPP (Markov modulated Poisson process) is an MAP whose D1 is given by a diagonal matrix. Unlike to general MAPs, MMPP never changes the phase at which an arrival occurs.

gmmp generates an object of gmmpp, which is exactly same as MMPP. In the estimation algorithm, gmmp class uses an approximate method.

Value

map gives an object of general MAP. mmpp gives an object of MMPP with default parameters. gmmpp gives an object of MMPP which uses an approximate estimation algorithm.

Note

map and gmmpp require either size or (alpha, D0, D1).

See Also

erhmm, map.mmomt, map.jmoment, map.acf
**Examples**

```r
## create an MAP (full matrix) with 5 phases
map(5)

## create an MAP (full matrix) with 5 phases
map(size=5)

## create an MMPP with 5 states
mmpp(5)

## create an MMPP with 5 states for approximate estimation
gmmp(5)

## create an MAP with specific parameters
(param <- map(alpha=c(1,0,0),
             D0=rbind(c(-4,2,0),c(2,-5,1),c(1,0,-4)),
             D1=rbind(c(1,1,0),c(1,0,1),c(2,0,1)))

## marginal moments of MAP
map.mmom(k=3, map=param)

## joint moments of MAP
map.jmoment(lag=1, map=param)

## k-lag correlation
map.acf(map=param)
```

### Description

Parameters for MAP and MMPP.

### Objects from the Class

Objects are usually created by `map`, `mmpp` or `gmmp`.

### Slots

- `size`: the number of phases (internal states).
- `alpha`: a probability (row) vector to decide an initial phase.
- `D0`: a square matrix that means transition rates without arrivals.
- `D1`: a square matrix that means transition rates with arrivals. In the case of MMPP, D1 should be a diagonal matrix.
- `df`: the number of free parameters.
See Also

Classes \texttt{erhmm}.

Examples

```r
## create an MAP (full matrix) with 5 phases
map(5)

## create an MAP (full matrix) with 5 phases
map(size=5)

## create an MMPP with 5 states
mmpp(5)

## create an MMPP with 5 states for approximate
## estimation
gmmpp(5)

## create an MAP with specific parameters
(param <- map(alpha=c(1,0,0),
D0=rbind(c(-4,2,0),c(2,-5,1),c(1,0,-4)),
D1=rbind(c(1,1,0),c(1,0,1),c(2,0,1))))

## marginal moments of MAP
map.mmoment(k=3, map=param)

## joint moments of MAP
map.jmoment(lag=1, map=param)

## k-lag correlation
map.acf(map=param)
```

---

**map.acf**

\textit{Moments for Markovian arrival process (MAP)}

Description

Moments for MAP.

Usage

```r
map.mmoment(k, map)
map.jmoment(lag, map)
map.acf(map)
```
Arguments

- `map`: an object of S4 class of MAP (`map`, `gmmpp`).
- `k`: an integer of degrees of moments.
- `lag`: an integer of time lag for correlation.

Details

MAP parameters are $\alpha$, $D_0$ and $D_1$:

$$P = (-D_0)^{-1}D_1$$

and

$$sP = s.$$

Then the moments for MAP are marginal moment:

$$m_k = k!s(-D_0)^{-k}1,$$

joint moment;

$$s_{ij}(\text{lag}) = i!j!s(-D_0)^{-i}P^{\text{lag}}(-D_0)^{-j}1,$$

k-lag correlation (autocorrelation);

$$\rho(\text{lag}) = (s_{11}(\text{lag}) - m_2^2)/(m_2 - m_1^2)$$

Value

- `map.mmoment` gives a vector of up to k moments.
- `map.jmoment` gives a matrix of $s_{ij}(\text{lag}), i = 1,..,n, j = 1,..,n$ where n is the size of phases.
- `map.acf` gives a vector of up to n-lag correlation, where n is the size of phases.

See Also

- `map`, `gmmpp`, `erhmm`

Examples

```r
## create an MAP with specific parameters
tab1 <- map(alpha=c(1,0,0), 
D0=rbind(c(-4,2,0),c(2,-5,1),c(1,0,-4)), 
D1=rbind(c(1,1,0),c(1,0,1),c(2,0,1))))

## create an ER-HMM with specific parameters
tab2 <- erhmm(shape=c(2,3), alpha=c(0.3,0.7), 
rate=c(1.0,10.0), 
P=rbind(c(0.3, 0.7), c(0.1, 0.9))))

## marginal moments of MAP
map.mmoment(k=3, map=tab1)
map.mmoment(k=3, map=as(tab2, "map"))
```
## Description

estimates MAP parameters from grouped data.

## Usage

```r
mapfit.group (map, counts, breaks, intervals, instant,
stationary = TRUE, control = list(), verbose = list(), ...)
```

## Arguments

- **map**: S4 class for MAP. The estimation algorithm is selected depending on the class.
- **counts**: a vector for the number of arrivals in time interval.
- **breaks**: a vector for time sequence to determine time interval. This is equivalent to `cumsum(intervals)`. If this is missing, it is assigned to `0:length(counts)`.
- **intervals**: a vector for a sequence of time length for intervals. This is equivalent to `diff(breaks)`. If this is missing, it is assigned to `rep(1,length(counts))`.
- **instant**: a vector of integer to indicate whether an arrival occurs at the last time of interval. If instant is 1, an arrival occurs at the last time of interval. If instant is 0, no arrival occurs at the last time of interval. By using instant, time point data can be expressed by grouped data class. If instant is missing, it is given by `rep(0,length(counts))`, i.e., there are no arrivals at the end of interval.
- **stationary**: a logical value that determines whether initial probability is given by a stationary vector of underlying Markov process or not.
- **control**: a list of parameters for controlling the fitting process.
- **verbose**: a list of parameters for displaying the fitting process.
- **...**: further arguments for methods.
Value

returns a list with components, which is an object of S3 class `mapfit.result`:

- **model**: an object for estimated MAP class (map, erhmm).
- **llf**: a value of the maximum log-likelihood.
- **df**: a value of degrees of freedom of the model.
- **aic**: a value of Akaike information criterion.
- **iter**: the number of iterations.
- **convergence**: a logical value for the convergence of estimation algorithm.
- **ctime**: computation time (user time).
- **stationary**: a logical value for the argument stationary.
- **data**: an object for MAP data class
- **aerror**: a value of absolute error for llf at the last step of algorithm.
- **rerror**: a value of relative error for llf at the last step of algorithm.
- **control**: a list of the argument of control.
- **verbose**: a list of the argument of verbose.
- **call**: the matched call.

See Also

`mapfit.point.map` and `gmmpp`

Examples

```r
## load trace data
data(BCpAug89)
BCpAug89s <- head(BCpAug89, 50)

## make grouped data
BCpAug89.group <- hist(cumsum(BCpAug89s),
                        breaks=seq(0, 0.15, 0.005),
                        plot=FALSE)

## MAP fitting for general MAP
(result1 <- mapfit.group(map=map(2),
                          counts=BCpAug89.group$counts,
                          breaks=BCpAug89.group$breaks))

## MAP fitting for MMPP
(result2 <- mapfit.group(map=mmpp(2),
                          counts=BCpAug89.group$counts,
                          breaks=BCpAug89.group$breaks))

## MAP fitting with approximate MMPP
(result3 <- mapfit.group(map=gmmpp(2),
                          counts=BCpAug89.group$counts,
                          breaks=BCpAug89.group$breaks))
```
mapfit.point

MAP fitting with time point data

Description

estimates MAP parameters from time point data.

Usage

mapfit.point (map, x, intervals, stationary = TRUE,
method = c("all", "increment"), lbound = 1, ubound = NULL,
control = list(), verbose = list(), ...)

Arguments

map an object of S4 class for MAP. The estimation algorithm is selected depending on the class.
x a vector for time sequence of arrivals. This is equivalent to cumsum(intervals). Either time or diffIntervals should be given.
intervals a vector for the data for intrarrival time. This is equivalent to diff(c(0,x)). Either time or diffIntervals should be given.
stationary a logical value that determine whether initial probability is given by a stationary vector of underlying Markov process or not.
method the name of estimation method for ER-HMM (erhmm).
lbound a value for lower limit for the number of states in ER-HMM (erhmm).
ubound a value for upper limit for the number of states in ER-HMM (erhmm).
control a list of parameters for controlling the fitting process.
verbose a list of parameters for displaying the fitting process.
... further arguments for methods.
**Value**

returns a list with components, which is an object of S3 class `map.fit.result`:

- `model`: an object for estimated MAP class (`map`, `erhmm`).
- `llf`: a value of the maximum log-likelihood.
- `df`: a value of degrees of freedom of the model.
- `aic`: a value of Akaike information criterion.
- `iter`: the number of iterations.
- `convergence`: a logical value for the convergence of estimation algorithm.
- `ctime`: computation time (user time).
- `stationary`: a logical value for the argument `stationary`.
- `data`: an object for MAP data class.
- `aerror`: a value of absolute error for `llf` at the last step of algorithm.
- `rerror`: a value of relative error for `llf` at the last step of algorithm.
- `control`: a list of the argument of `control`.
- `verbose`: a list of the argument of `verbose`.
- `call`: the matched call.

**See Also**

- `mapfit.group.map` and `erhmm`

**Examples**

```r
## load trace data
data(BCpAug89)
BCpAug89s <- head(BCpAug89, 50)

## MAP fitting for general MAP
(result1 <- mapfit.point(map=map(2), x=cumsum(BCpAug89s)))

## MAP fitting for MMPP
(result2 <- mapfit.point(map=mmpp(2), x=cumsum(BCpAug89s)))

## MAP fitting for ER-HMM
(result3 <- mapfit.point(map=erhmm(3), x=cumsum(BCpAug89s)))

## marginal moments for estimated MAP
map.mmoment(k=3, map=result1$model)
map.mmoment(k=3, map=result2$model)
map.mmoment(k=3, map=as(result3$model, "map"))

## joint moments for estimated MAP
map.jmoment(lag=1, map=result1$model)
map.jmoment(lag=1, map=result2$model)
map.jmoment(lag=1, map=as(result3$model, "map"))
```
Phase-Type (PH) Distribution

Description

Density function, distribution function and random generation for the PH distribution, and a function to generate an object of \textit{ph}.

Usage

\begin{verbatim}
ph(size, alpha, Q, xi, class = "CsparseMatrix")
dph(x, ph = ph(1), log = FALSE)
pph(q, ph = ph(1), lower.tail = TRUE, log.p = FALSE)
rph(n, ph = ph(1))
\end{verbatim}

Arguments

- \texttt{size}: a value for the number of phases.
- \texttt{alpha}: a vector for the initial probabilities of PH distribution.
- \texttt{Q}: an object of Matrix class for the infinitesimal generator of PH distribution.
- \texttt{xi}: a vector for the exit rates of PH distribution.
- \texttt{class}: name of Matrix class for \texttt{Q}.
- \texttt{x, q}: vectors of quantiles.
- \texttt{p}: a vector of probabilities.
- \texttt{n}: number of observations.
- \texttt{ph}: an object of S4 class of PH (\textit{ph}).
- \texttt{log}: logical; if TRUE, the log density is returned.
- \texttt{lower.tail}: logical; if TRUE, probabilities are \(P[X \leq x]\), otherwise, \(P[X > x]\).
- \texttt{log.p}: logical; if TRUE, the log probability is returned.

Details

The PH distribution with parameters \(\alpha, Q\) and \(\xi\): Cumulative probability function;

\[ F(q) = 1 - \alpha \exp(Qq) \]

Probability density function;

\[ f(x) = \alpha \exp(Qx)\xi \]
Value

ph gives an object of general PH distribution. dph gives the density function, pph gives the distribution function, and rph generates random samples.

Note

ph requires either size or (alpha, Q, xi). rph for ph is too slow. It is recommended to use rph for cf1.

See Also

cf1, herlang

Examples

```r
## create a PH (full matrix) with 5 phases
(param1 <- ph(5))

## create a PH (full matrix) with 5 phases
(param1 <- ph(size=5))

## create a PH with specific parameters
(param2 <- ph(alpha=c(1,0,0),
              Q=rbind(c(-4,2,0),c(2,-5,1),c(1,0,-1)),
              xi=c(2,2,0)))

## p.d.f. for 0, 0.1, ..., 1
(dph(x=seq(0, 1, 0.1), ph=param2))

## c.d.f. for 0, 0.1, ..., 1
(pph(q=seq(0, 1, 0.1), ph=param2))

## generate 10 samples
(rph(n=10, ph=param2))
```

ph-class

Class of general PH distributions

Description

Parameters for a general PH distribution.

Objects from the Class

Objects are usually created by a ph.
Slots

size: the number of phases (transient states).
alpha: a probability (row) vector to decide an initial phase.
Q: a square matrix that means transition rates between phases.
xi: a column vector for exiting rates from phases to an absorbing state.
df: the number of free parameters.

Methods

ph.moment signature(ph = "ph"): ...

See Also

Classes cf1 and herlang.

Examples

## create a PH (full matrix) with 5 phases
(param1 <- ph(5))

## create a PH (full matrix) with 5 phases
(param1 <- ph(size=5))

## create a PH with specific parameters
(param2 <- ph(alpha=c(1,0,0),
            Q=rbind(c(-4,2,0),c(2,-5,1),c(1,0,-1)),
            xi=c(2,2,0)))

## p.d.f. for 0, 0.1, ..., 1
(dph(x=seq(0, 1, 0.1), ph=param2))

## c.d.f. for 0, 0.1, ..., 1
(pph(q=seq(0, 1, 0.1), ph=param2))

## generate 10 samples
(rph(n=10, ph=param2))

---

| ph.moment | Moments for Phase-Type (PH) Distribution |

Description

Moments for PH distribution.
Usage

```r
ph.mean(ph)
ph.var(ph)
## S4 method for signature 'ANY,ph'
ph.moment(k, ph, ...)
## S4 method for signature 'ANY,herlang'
ph.moment(k, ph, ...)
```

Arguments

- `ph`: an object of S4 class of PH (`ph`) or Hyper-Erlang (`herlang`).
- `k`: an integer of degrees of moments.
- `...`: further arguments for methods.

Details

The PH distribution with parameters $\alpha$, $Q$ and $xi$: $k$-th moment;

$$k!\alpha(-Q)^{-k} 1$$

Value

`ph.mean` and `ph.var` give mean and variance of PH. `ph.moment` gives a vector of up to $k$ moments.

Note

`ph.moment` is a generic function for `ph` and `herlang`.

See Also

`ph`, `cf1`, `herlang`

Examples

```r
## create a PH with specific parameters
(param1 <- ph(alpha=c(1,0,0),
              Q=rbind(c(-4,2,0),c(2,-5,1),c(1,0,-1)),
              xi=c(2,2,0)))

## create a CF1 with specific parameters
(param2 <- cf1(alpha=c(1,0,0), rate=c(1.0,2.0,3.0)))

## create a hyper Erlang with specific parameters
(param3 <- herlang(shape=c(2,3), mixrate=c(0.3,0.7),
                    rate=c(1.0,10.0)))

## mean
ph.mean(param1)
ph.mean(param2)
ph.mean(param3)
```
### phfit.3mom

**PH fitting with three moments**

**Description**

estimates PH parameters from three moments.

**Usage**

```r
phfit.3mom(m1, m2, m3, method = c("Osogami06", "Bobbio05"),
max.phase = 50, epsilon = sqrt(.Machine$double.eps))
```

**Arguments**

- `m1` a value of the first moment.
- `m2` a value of the second moment.
- `m3` a value of the third moment.
- `method` the name of moment matching method.
- `max.phase` an integer for the maximum number of phases in the method "Osogami06".
- `epsilon` a value of precision in the method "Osogami06".

**Value**

returns an object of S4 class of general PH `ph`.

**Note**

The method "Osogami06" checks the first three moments on whether there exists a PH whose three moments match to them. In such case, the method "Bobbio05" often returns an error.

**References**


**phfit.density**

*PH fitting with density function*

**Description**

estimates PH parameters from density function.

**Usage**

```r
phfit.density(ph, f, deformula = zero.to.inf,
              weight.zero = .Machine$double.eps,
              weight.reltol = sqrt(.Machine$double.eps),
              method = c("all", "increment"), lbound = 1, ubound = NULL,
              control = list(), verbose = list(), ...)```

**Arguments**

- **ph**: an object of S4 class for MAP. The estimation algorithm is selected depending on the class.
- **f**: a function object for a density function.
- **deformula**: an object for formulas of numerical integration. It is not necessary to change it when the density function is defined on the positive domain [0,\(\infty\)].

**Examples**

```r
## Three moment matching
## Moments of Weibull(shape=2, scale=1); (0.886227, 1.0, 1.32934)
(result1 <- phfit.3mom(0.886227, 1.0, 1.32934))

## Three moment matching
## Moments of Weibull(shape=2, scale=1); (0.886227, 1.0, 1.32934)
(result2 <- phfit.3mom(0.886227, 1.0, 1.32934, method="Bobbio05"))

## mean
ph.mean(result1)
ph.mean(result2)

## variance
ph.var(result1)
ph.var(result2)

## up to 5 moments
ph.moment(5, result1)
ph.moment(5, result2)```
weight.zero          a absolute value which is regarded as zero in numerical integration.
weight.reltol       a value for precision of numerical integration.
method              the name of estimation method for hyper Erlang (herlang).
lbound              a value for lower limit for the number of states in hyper Erlang (herlang).
ubound              a value for upper limit for the number of states in hyper Erlang (herlang).
control             a list of parameters for controlling the fitting process.
verbose             a list of parameters for displaying the fitting process.
...                 further arguments for methods, which are also used to send the arguments to density function.

Value

returns a list with components, which is an object of S3 class phfit.result;

model       an object for estimated PH class (ph, cf1, herlang).
llf         a value of the maximum log-likelihood (a negative value of the cross entropy).
df          a value of degrees of freedom of the model.
aic         a value of Akaike information criterion (this is not meaningless in this case).
iter        the number of iterations.
convergence a logical value for the convergence of estimation algorithm.
cstime      computation time (user time).
data        an object for MAP data class
aerror      a value of absolute error for llf at the last step of algorithm.
rerror      a value of relative error for llf at the last step of algorithm.
control     a list of the argument of control.
verbose     a list of the argument of verbose.
call        the matched call.

Note

Any of density function can be applied to the argument f, where f should be defined f <- function(x, ...). The first argument of f should be an integral parameter. The other parameters are set in the argument ... of phfit.density. The truncated density function can also be used directly.

See Also

phfit.point, phfit.group, ph, cf1 and herlang
Examples

# PH fitting with grouped data

```
# PH fitting for general PH
result1 <- phfit.group(ph=ph(2), f=dnorm,
               mean=3, sd=1))

# PH fitting for CF1
(result2 <- phfit.group(ph=cf1(2), f=dnorm,
                      mean=3, sd=1))

# PH fitting for hyper Erlang
(result3 <- phfit.group(ph=herlang(3), f=dnorm,
                      mean=3, sd=1))

# mean
ph.mean(result1$model)
ph.mean(result2$model)
ph.mean(result3$model)

# variance
ph.var(result1$model)
ph.var(result2$model)
ph.var(result3$model)

# up to 5 moments
ph.moment(5, result1$model)
ph.moment(5, result2$model)
ph.moment(5, result3$model)
```

**Description**

estimates PH parameters from grouped data.

**Usage**

```
phfit.group(ph, counts, breaks, intervals, instant,
            method = c("all", "increment"), lbound = 1, ubound = NULL,
            control = list(), verbose = list(), ...)
```
Arguments

- **ph**: an object of S4 class for MAP. The estimation algorithm is selected depending on this class.
- **counts**: a vector of the number of points in intervals.
- **breaks**: a vector for a sequence of points of boundaries of intervals. This is equivalent to `c(0, cumsum(intervals))`. If this is missing, it is assigned to `0:length(counts)`.
- **intervals**: a vector of time lengths for intervals. This is equivalent to `diff(breaks)`. If this is missing, it is assigned to `rep(1, length(counts))`.
- **instant**: a vector of integers to indicate whether sample is drawn at the last of interval. If instant is 1, a sample is drawn at the last of interval. If instant is 0, no sample is drawn at the last of interval. By using instant, point data can be expressed by grouped data. If instant is missing, it is given by `rep(0L, length(counts))`, i.e., there are no samples at the last of interval.
- **method**: the name of estimation method for hyper Erlang (`herlang`).
- **lbound**: a value for lower limit for the number of states in hyper Erlang (`herlang`).
- **ubound**: a value for upper limit for the number of states in hyper Erlang (`herlang`).
- **control**: a list of parameters for controlling the fitting process.
- **verbose**: a list of parameters for displaying the fitting process.
- **...**: further arguments for methods.

Value

returns a list with components, which is an object of S3 class `phfit.result`:

- **model**: an object for estimated PH class (`ph`, `cf1`, `herlang`).
- **llf**: a value of the maximum log-likelihood.
- **df**: a value of degrees of freedom of the model.
- **aic**: a value of Akaike information criterion.
- **iter**: the number of iterations.
- **convergence**: a logical value for the convergence of estimation algorithm.
- **ctime**: computation time (user time).
- **data**: an object for MAP data class
- **aerror**: a value of absolute error for llf at the last step of algorithm.
- **rerror**: a value of relative error for llf at the last step of algorithm.
- **control**: a list of the argument of control.
- **verbose**: a list of the argument of verbose.
- **call**: the matched call.

Note

In this method, we can handle truncated data using `NA` and `Inf`:

```
phfit.group(ph=cf1(5), counts=c(countsdata, NA), breaks=c(breakdata, +Inf))
```

`NA` means missing of count data at the conredponding interval, and `Inf` ia allowed to put the last of breaks or intervals which represents a special interval (the last break point, infinity).
### phfit.point

**PH fitting with point data**

#### Description

estimates PH parameters from point data.

#### Usage

```r
phfit.point(ph, x, weights, method = c("all", "increment"), lbound = 1, ubound = NULL, control = list(), verbose = list(), ...)
```
Arguments

- **ph**: an object of S4 class for MAP. The estimation algorithm is selected depending on this class.
- **x**: a vector for point data.
- **weights**: a vector of weights for points.
- **method**: the name of estimation method for hyper Erlang (herlang).
- **lboun**: a value for lower limit for the number of states in hyper Erlang (herlang).
- **uboun**: a value for upper limit for the number of states in hyper Erlang (herlang).
- **control**: a list of parameters for controlling the fitting process.
- **verbose**: a list of parameters for displaying the fitting process.
- **...**: further arguments for methods.

Value

returns a list with components, which is an object of S3 class phfitN.result;

- **model**: an object for estimated PH class (ph, cf1, herlang).
- **llf**: a value of the maximum log-likelihood.
- **df**: a value of degrees of freedom of the model.
- **aic**: a value of Akaike information criterion.
- **iter**: the number of iterations.
- **convergence**: a logical value for the convergence of estimation algorithm.
- **ctime**: computation time (user time).
- **data**: an object for MAP data class
- **aerror**: a value of absolute error for llf at the last step of algorithm.
- **rerror**: a value of relative error for llf at the last step of algorithm.
- **control**: a list of the argument of control.
- **verbose**: a list of the argument of verbose.
- **call**: the matched call.

See Also

phfit.group, phfit.density, ph, cf1 and herlang

Examples

```r
## make sample
wsample <- rweibull(n=100, shape=2, scale=1)

## PH fitting for general PH
(result1 <- phfit.point(ph=ph(2), x=wsample))

## PH fitting for CF1
```
(result2 <- phfit.point(ph=cf1(2), x=wsample))

## PH fitting for hyper Erlang
(result3 <- phfit.point(ph=herlang(3), x=wsample))

## mean
ph.mean(result1$model)
ph.mean(result2$model)
ph.mean(result3$model)

## variance
ph.var(result1$model)
ph.var(result2$model)
ph.var(result3$model)

## up to 5 moments
ph.moment(5, result1$model)
ph.moment(5, result2$model)
ph.moment(5, result3$model)
Index

*Topic classes
  cf1-class, 5
  erhmm-class, 7
  herlang-class, 10
  map-class, 13
  ph-class, 21
*Topic datasets
  BcpAug89, 3
*Topic distribution
  cf1, 4
  herlang, 9
  map.acf, 14
  ph, 20
  ph.moment, 22
*Topic package
  mapfit-package, 2

BCpAug89, 3

cf1, 4, 4, 5, 11, 21–23, 26, 28–30
cf1-class, 5

dherlang (herlang), 9
dph (ph), 20

erhmm, 6, 6, 7, 12, 14, 15, 17–19
erhmm-class, 7

gmmp, 7, 8, 12, 13, 15, 17
gmmp.map, 12
gmmp-class (map-class), 13

herlang, 4, 6, 9, 10, 21–23, 26, 28–30
herlang-class, 10

map, 7, 8, 12, 13, 15, 17, 19
map-class, 13
map.acf, 7, 12, 14
map.jmoment, 7, 12
map.jmoment (map.acf), 14
map.mmoment, 7, 12

map.mmoment (map.acf), 14
mapfit (mapfit-package), 2
mapfit-package, 2
mapfit.group, 2, 16, 19
mapfit.point, 2, 17, 18
mmpp, 13
mmpp.map, 12

ph, 4–6, 10, 11, 20, 20, 21, 23–26, 28–30
ph-class, 21
ph.mean (ph.moment), 22
ph.moment, 5, 22, 25
ph.moment, ANY, herlang-method
  (ph.moment), 22
ph.moment, ANY, ph-method (ph.moment), 22
ph.moment-method (ph.moment), 22
ph.var (ph.moment), 22
pherlang (herlang), 9
phfit (mapfit-package), 2
phfit.3mom, 2, 24
phfit.density, 2, 25, 29, 30
phfit.group, 2, 26, 27, 30
phfit.point, 2, 26, 29, 29
pph (ph), 20

rherlang (herlang), 9
rph (ph), 20