Package 'msSurv'

April 11, 2015

Version 1.2-2

Date 2015-04-10

Title Nonparametric Estimation for Multistate Models

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Depends R (>= 2.0), graph

Imports methods, class, lattice

Suggests KMsurv, Rgraphviz

Description
Nonparametric estimation for right censored, left truncated time to event data in multistate models.

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Collate msSurv-Classes.R msSurv-Methods.R msSurv-internal.R msSurv-user.R

NeedsCompilation no

Repository CRAN

Date/Publication 2015-04-11 01:16:29

R topics documented:

EntryExit	*State Entry and Exit Time Distributions at Time t*

Description

This function displays the state entry and exit time distributions at time t. The function also displays the corresponding variance estimates if the user requests them.

Usage

```
EntryExit(object, t="last", deci=4, var=FALSE, norm=TRUE)
```

Arguments

object	A msSurv object.
t	The time to find state entry/exit distributions. Default is "last" which is the highest (or "last") event time.
deci	Numeric argument specifying number of decimal places for estimates. Default is 4.
var	Logical argument to determine if the variance is displayed. Default is FALSE. If variance estimates are NULL, an error message will print.
norm	Logical argument to determine whether normalized or non-normalized (subdistribution) functions are displayed. Default is normalized distributions.

Details

Display of the state entry and exit time distributions and corresponding variance for multistate models at each state in the system where computation makes sense.

Value

Returns (invisibly) a list consisting of the state entry / exit distributions (either `entry.norm` and `exit.norm` or `entry.sub` and `exit.sub`), and (optionally) the variance estimates (either `entry.var.norm` and `exit.var.norm` or `entry.var.sub` and `exit.var.sub`).

Note

State entry distributions (and corresponding variance estimates) are displayed for all states where entry into the state occurs. State exit distributions (and corresponding variance estimates) are displayed for all states where exit from the state occurs.

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References

Nicole Ferguson, Somnath Datta, Guy Brock (2012). msSurv: An R Package for Nonparametric Estimation of Multistate Models. Journal of Statistical Software, 50(14), 1-24. URL http://www.jstatsoft.org/v50/i14/.

Datta, S. and Satten G.A. (2001). Validity of the Aalen-Johansen estimators of stage occupation probabilities and Nelson-Aalen estimators of integrated transition hazards for non-Markov models. Statistics and Probability Letters, 55(4): 403-411.

Datta S, Satten GA (2002). Estimation of Integrated Transition Hazards and Stage Occupation Probabilities for Non-Markov Systems under Dependent Censoring. Biometrics, 58(4), 792-802.

See Also

msSurv

Examples

```
## Row elements of data
p1 <- c(1,0,0.21,1,3)
p2 <- c(2,0,0.799,1,2)
p22 <- c(2,0.799,1.577,2,3)
p3 <- c(3,0,0.199,1,0)

## Combining data into a matrix
ex1 <- rbind(p1,p2,p22,p3)
colnames(ex1) <- c("id", "start", "stop", "start.stage", "end.stage")
ex1 <- data.frame(id=ex1[,1], start=ex1[,2], stop=ex1[,3],
                  start.stage=ex1[,4], end.stage=ex1[,5])


## Inputting nodes & edges of the tree structure
Nodes <- c("1","2","3") # states in MSM
Edges <- list("1"=list(edges=c("2","3")),"2"=list(edges=c("3")),
          "3"=list(edges=NULL)) ## allowed transitions between states
                                ## edges=NULL implies terminal node

## Specifying tree
treeobj <- new("graphNEL", nodes=Nodes, edgeL=Edges,
               edgemode="directed")

## Running msSurv
ans1 <- msSurv(ex1,treeobj)
EntryExit(ans1,t=0.8)
```

LTRCdata   *Simulated Left Truncated, Right Censored Data Set for an Irreversible Illness-Death Model*

Description

Simulated data from an irreversible three-state illness-death model with data subject to independent right censoring and left truncation.

Usage

```
data(LTRCdata)
```

Format

A data frame with 1000 individuals with the following 4 variables.

id Identification number

start Left truncation time, i.e.: start time for the period of observation after the individual enters state j

stop Transition time

start.stage State transitioning FROM

end.stage State transitioning TO

Details

A data set of 1000 individuals was simulated from an irreversible three-state illness-death model with data subject to independent right censoring and left truncation. All individuals were assumed to starte in state 1 at time 0. Individuals remained in state 1 until they transitioned to the transient state 2 (ill) or the terminal state 3 (death). Individuals in state 2 remained there until they transition to the terminal state 3 (death). All times were rounded to the fourth decimal place for clarity of presentation.

References

Nicole Ferguson, Somnath Datta, Guy Brock (2012). msSurv: An R Package for Nonparametric Estimation of Multistate Models. Journal of Statistical Software, 50(14), 1-24. URL http://www.jstatsoft.org/v50/i14/.

Examples

```
data(LTRCdata)

#######################################################################
##                    Code used to generate data                    ##
#######################################################################

## Specifying the tree structure for the simulation
Nodes <- c("1","2","3") #states possible in MSM
Edges <- list("1"=list(edges=c("2","3")),"2"=list(edges=c("3")),
          "3"=list(edges=NULL)) #transitions from each state

RCLTtree <- new("graphNEL",nodes=Nodes,edgeL=Edges,edgemode="directed")

## Simulating the data
```

```
set.seed(123)
n <- 1000
censor <- round(rlnorm(n, meanlog=0, sdlog=2),digits=4)

## 80% of sample is LT, rest has start time of 0
p1 <- n*0.8
left.p1 <- round(rlnorm(p1, meanlog=-1, sdlog=2),digits=4) ## start time
left.p2 <- rep(0, n-p1) ## start time
left <- c(left.p1, left.p2)
ill <- round(rweibull(n,2),digits=4)
death1 <- round(rweibull(n,2),digits=4)
## 2nd transition time for those entering illness state first
death2 <- round(qweibull(pweibull(ill, shape=2) + runif(n, 0, 1)*(1 -
                            pweibull(ill, shape=2)), shape=2), digits=4)
## use death2 for indiv w ill < death1, death1 for those w/death1 < ill
death <- ifelse(ill < death1, death2, death1)
last.tran <- pmin(death, censor)

## those who are never visible to investigator
hidden <- which(left > last.tran)
length(hidden) ## 407

## indiv starting in state 2 (illness)
ill.start <- which(left > ill & left < last.tran & ill < last.tran)
length(ill.start)  ## 28

## remainder should be indiv starting in state 1 (wellness)
## can double-check w/the following ..
first.tran <- pmin(death, pmin(ill, censor))
well.start <- which(left < first.tran)
length(c(hidden, well.start, ill.start))    ## 1000

x <- cbind(left, death, censor, ill)

## those who enter in state 1
t1 <-  pmin(ill[well.start], death[well.start], censor[well.start])
end.stage <- ifelse(censor[well.start] < death[well.start] &
                        censor[well.start] < ill[well.start], 0,
                    ifelse(ill[well.start] < death[well.start], 2, 3))
data1 <- data.frame(id=1:length(t1), start=left[well.start], stop=t1,
                    start.stage=1, end.stage=end.stage)

## those transitioning to stage 2
ind <- which(data1$end.stage==2)
t2 <- pmin(death[well.start][ind], censor[well.start][ind])
end.stage2 <- ifelse(censor[well.start][ind] < t2, 0, 3)
data2 <- data.frame(id=ind, start=data1$stop[ind], stop=t2,
                    start.stage=data1$end.stage[ind], end.stage=end.stage2)

## those who enter in stage 2 after truncation
if(length(ill.start) > 0) {
  t3 <-  pmin(death[ill.start], censor[ill.start]) ## same as last.tran[ill.start]
  end.stage3 <- ifelse(censor[ill.start] < death[ill.start], 0, 3)
```

```
  data2a <- data.frame(id=(1:length(t3)) + max(data1$id),
                         start=left[ill.start],
                         stop=t3, start.stage=2, end.stage=end.stage3)
  data <- rbind(data1, data2, data2a)
}

if(length(ill.start)==0)  data <- rbind(data1, data2)

LTRCdata <- with(data, data[order(id, stop), ])
```

---

msSurv   *Nonparametric Estimation for Multistate Models*

Description

The function uses the counting process and at risk set of event times to calculate the state occupation probabilities, as well as the state entry and exit time distributions, for a general, possibly non-Markov, model. It also calculates the transition probability matrices and covariance matrices for the state occupation probabilities and transition probabilities.

Usage

```
msSurv(Data, tree, cens.type="ind", LT=FALSE, bs=FALSE, B=200)
```

Arguments

Data	Data with counting-process style of input. Columns should be named "id", "start" (needed if LT=TRUE, optional otherwise), "stop", "start.stage", and "end.stage".
tree	A [graphNEL](#) graph with the nodes and edges of the multistate model.
cens.type	A character string specifying whether censoring is independent ("ind") or state dependent ("dep"). Default is "ind".
LT	Logical argument specifying whether data are subject to left truncation. Default is FALSE.
bs	Logical argument specifying whether to use the bootstrap to calculate the variance. The bootstrap is needed for the variance of the state entry/exit distributions, for state-dependent censoring, and for state occupation probabilities when there is more than one possible initial starting state. Default is FALSE.
B	The number of bootstrap iterations, when bs=TRUE.

Details

Data are from a possibly non-Markovian multistate model with a directed tree structure and subject to right censoring and possibly left truncation.

State 0 is reserved as the censoring state.

State occupation probabilities are calculated according to the formula given in Datta & Satten (2001).

State entry and exit time distributions are calculated using state occupation probabilities.

The transition probability matrices are estimates using the Aalen-Johansen estimator described in Andersen et al. (1993). The transition probability is the (i,j)th entry of the transition matrix. Datta and Satten (2001) showed that the Aalen-Johansen estimator remained valid for non-Markov systems.

The covariance matrix for transition probability is computed componentwise following formula (4.4.20) in Andersen et al. (1993, p. 295) for independent censoring. The bootstrap is needed for state-dependent censoring, and also for the variance of the state entry/exit distributions, and for state occupation probabilities when there is more than one possible initial starting state.

Value

An object of S4 class msSurv with the following slots:

tree	A graphNEL object with the nodes and edges of the multistate model.
ns	Number of states.
et	Event times.
pos.trans	Possible transitions between states.
nt.states	Non-terminal states.
dNs	The counting process.
Ys	The "at-risk" set.
sum_dNs	Counting process for total transitions out of each state.
dNs.K	The weighted counting process.
Ys.K	The weighted "at-risk" set.
sum_dNs.K	Weighted counting process for total transitions out of each state.
ps	State occupation probabilities.
AJs	An array containing matrices of Aalen-Johansen estimates.
I.dA	Array with all the I+dA transition matrices for Aalen-Johansen computation.
cov.AJs	Variance-covariance matrices of the transition probabilities (A-J estimates).
var.sop	Variance of state occupation probability.
cov.dA	A matrix containing the covariance of dA matrices used for computation of cov(P(s,t)).
Fnorm	Normalized state entry time distributions.
Fsub	State entry time sub-distributions.
Gnorm	Normalized state exit time distributions.
Gsub	State exit time sub-distributions.
Fnorm.var	Variance of the normalized state entry time distributions.
Fsub.var	Variance of the state entry time sub-distributions.
Gnorm.var	Variance of normalized state exit time distributions.
Gsub.var	Variance of state exit time sub-distributions.

Note

State 0 is reserved as the censoring state.

Author(s)

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References

Nicole Ferguson, Somnath Datta, Guy Brock (2012). msSurv: An R Package for Nonparametric Estimation of Multistate Models. Journal of Statistical Software, 50(14), 1-24. URL http://www.jstatsoft.org/v50/i14/.

Andersen, P.K., Borgan, O., Gill, R.D. and Keiding, N. (1993). Statistical models based on counting processes. Springer Series in Statistics. New York, NY: Springer.

Datta, S. and Satten G.A. (2001). Validity of the Aalen-Johansen estimators of stage occupation probabilities and Nelson-Aalen estimators of integrated transition hazards for non-Markov models. Statistics and Probability Letters, 55(4): 403-411.

Datta S, Satten GA (2002). Estimation of Integrated Transition Hazards and Stage Occupation Probabilities for Non-Markov Systems under Dependent Censoring. Biometrics, 58(4), 792-802.

See Also

See the description of the plot, print, and summary methods in the help page for S4 class msSurv.

Examples

```
## 3-state illness-death multistate model (no left-truncation)

## Row data for 3 individuals
## Data in the form "id", "start", "stop", "start.stage", "end.stage"
p1  <- c(1,0,0.21,1,3)
p2  <- c(2,0,0.799,1,2)
p22 <- c(2,0.799,1.577,2,3)
p3  <- c(3,0,0.199,1,0)

## Combining data into a matrix
ex1 <- rbind(p1,p2,p22,p3)
colnames(ex1) <- c("id", "start", "stop", "start.stage", "end.stage")
ex1 <- data.frame(id=ex1[,1], start=ex1[,2], stop=ex1[,3],
                  start.stage=ex1[,4], end.stage=ex1[,5])


## Inputting nodes & edges of the tree structure
Nodes <- c("1","2","3") # states in MSM
Edges <- list("1"=list(edges=c("2","3")),"2"=list(edges=c("3")),
         "3"=list(edges=NULL)) ## allowed transitions between states
                               ## edges=NULL implies terminal node

## Specifying tree
treeobj <- new("graphNEL", nodes=Nodes, edgeL=Edges,
```

```
                         edgemode="directed")

   ans1 <- msSurv(ex1, treeobj)

   ## printing msSurv object 'ans1'
   print(ans1)

   ## summary for msSurv object
   summary(ans1)

   ## plotting msSurv object 'ans1'
   plot(ans1, plot.type="stateocc")
   plot(ans1, plot.type="stateocc", states=c("1", "2"))
   plot(ans1, plot.type="transprob")
   plot(ans1, plot.type="entry.norm")
   plot(ans1, plot.type="exit.norm")

   ## 3-state illness-death multistate model WITH left-truncation

   ## Row data for 3 individuals
   ## Data in the form "id", "start", "stop", "start.stage", "end.stage"

   p1  <- c(1,  0.383,  1.400,  1,  0)
   p2  <- c(2,  0.698,  0.999,  1,  2)
   p22 <- c(2,  0.999,  1.180,  2,  0)
   p3  <- c(3,  0.249,  0.391,  1,  2)
   p32 <- c(3,  0.391,  0.513,  2,  3)

   ex2 <- rbind(p1, p2, p22, p3, p32)
   colnames(ex2) <- c("id",  "start",  "stop",  "start.stage",  "end.stage")
   ex2 <- data.frame(ex2)

   ## inputting nodes & edgest of the tree structure
   Nodes <- c("1", "2", "3")
   Edges <- list("1"=list(edges=c("2", "3")), "2"=list(edges=c("3")), "3"=list(edges=NULL))
   treeobj <- new("graphNEL", nodes=Nodes, edgeL=Edges, edgemode="directed")

   ans2 <- msSurv(ex2, treeobj, LT=TRUE)

   ## Summary for msSurv object 'ans2'
   summary(ans2) ## gives estimates for IQR event times
   summary(ans2,  all=TRUE) ## gives estimates for all event times
   ## Summary for state occupation probability only
   summary(ans2,  trans.pr=FALSE, dist=FALSE)
```

---

msSurv-class   *Class "msSurv"*

Description

The class "msSurv" contains nonparametric estimates for multistate models subject to right censoring and possibly left truncation by calling msSurv.

Objects from the Class

Objects can be created by calls of the form new("msSurv", ...). "msSurv" objects are also returned from function msSurv

Slots

tree: Object of class "graphNEL". A graphNEL object with nodes corresponding to the states in the multistate model and the edges corresponding to the allowed transitions.

ns: Object of class "numeric". The number of unique states in the multistate model.

et: Object of class "numeric". The event times.

pos.trans: Object of class "character". Possible transtitions between states.

nt.states: Object of class "character". The non-terminal states in the multistate model.

dNs: Object of class "array". A matrix containing the differential of the counting processes for the event times.

Ys: Object of class "array". A matrix containing the at risk sets for the event times.

sum_dNs: Object of class "array". A matrix containing the differential for the counting process for total transitions out of each state, at each event time.

dNs.K: Object of class "array". A matrix containing the differential of the weighted counting process described in Datta and Satten (2001).

Ys.K: Object of class "array". A matrix containing the weighted at risk sets described in Datta and Satten (2001).

sum_dNs.K: Object of class "array". A matrix containing the differential of the weighted counting process for total transitions out of each state, at each event time.

ps: Object of class "array". A matrix with state occupation probabilities for each state at each event time.

AJs: Object of class "array". An array containing matrices of Aalen-Johansen estimates (transition probabilities) at each event time.

I.dA: Object of class "array". A matrix containing the I+dA transition matrices for Aalen-Johansen computation.

cov.AJs: Object of class "array". An array containing the variance-covariance matrices for transition probabilities at each event time.

var.sop: Object of class "array". A matrix containing covariance estimates for the state occupation probabilities.

cov.dA: Object of class "array". A matrix containing the covariance of dA matrices used for computation of cov(P(s,t)).

Fnorm: Object of class "array". A matrix containing normalized state entry distributions. Note: "NA" is recorded for Fnorm at the initial state(s) (node(s)).

Fsub: Object of class "array". A matrix containing unnormalized (subdistribution) state entry distributions. Note: "NA" is recorded for Fsub at the initial state(s) (node(s)).

Gnorm: Object of class "array". A matrix containing normalized state exit distributions. Note: "NA" is recorded for Gnorm at the terminal state(s) (node(s)).

Gsub: Object of class "array". A matrix containing unnormalized (subdistribution) state exit distributions. Note: "NA" is recorded for Gsub at the terminal state(s) (node(s)).

Fnorm.var: Object of class "array or NULL". A matrix containing variance estimates for the normalized state entry distributions. Will be NULL if the user does not specify bs=TRUE.

Fsub.var: Object of class "array or NULL". A matrix containing variance estimates for the unnormalized (subdistribution) state entry distributions. Will be NULL if the user does not specify bs=TRUE.

Gnorm.var: Object of class "array or NULL". A matrix containing variance estimates for the normalized state exit distributions. Will be NULL if the user does not specify bs=TRUE.

Gsub.var: Object of class "array or NULL". A matrix containing variance estimates for the unnormalized (subdistribution) state exit distributions. Will be NULL if the user does not specify bs=TRUE.

Methods

ACCESSOR FUNCTIONS signature(object = "msSurv"): Accessor functions are defined for each of the slots in an msSurv object, e.g. tree, ns, et, etc. The accessor functions all have the same name as the corresponding slot name, and all have the same signature.

print signature(x = "msSurv"): Print method for "msSurv" objects.

show signature(object = "msSurv"): Show method for "msSurv" objects.

summary signature(object = "msSurv"): Summary function for "msSurv" objects.

Additional arguements:

digits=3 The number of significant digits to use for estimates. Defalt is 3.

all=FALSE Logical argument to determine whether summary information should be displayed for all event times or only for the key percentile time points (IQR). Default is FALSE where all=FALSE corresponds to only the IQR of event times being displayed in the summary output.

times=NULL Numeric vector of time-points at which to present summary information. Overrides all if supplied.

ci.fun="linear" Transformation applied to confidence intervals. Possible choices are "linear", "log", "log-log", and "cloglog". Default is "linear".

ci.level=0.95 Confidence level. Default is 0.95.

stateocc=TRUE Logical argument specifying whether state occupation probabilities should be displayed. Default is TRUE.

trans.pr=TRUE Logical argument specifying whether state transition probabilities should be displayed. Default is TRUE.

dist=TRUE Logical argument specifying whether state entry / exit distributions should be displayed. Default is TRUE.

DS=FALSE Logical argument specifying whether Datta-Satten weighted counting processes. Default is FALSE.

plot signature(x = "msSurv", y = "missing"): Plotting method for "msSurv" objects.

  Additional arguments:

  states="ALL" States in the multistate model to be plotted. Default is all states in the system. User may specify individual states or multiple states to plot.

  trans="ALL" Transitions in the multistate model to be plotted. Default is all transitions. Transitions should be entered with a space between the two states, e.g.: "1 1".

  CI=TRUE A logical argument to specify whether pointwise confidence intervals should be plotted. If the user specifies CI=FALSE, only the estimates are plotted. If the user specifies CI=TRUE, plots of each estimate and its corresponding confidence intervals are created (if appropriate variances are available). The default is TRUE.

  ci.level=0.95 Confidence level. Default is 0.95.

  ci.trans="linear" Transformation applied to confidence intervals. Possible choices are "linear", "log", "log-log", and "cloglog". Default is "linear".

  plot.type="stateocc" Determines the type of estimate to be plotted. User may specify "transprob" for transition probability plots, "stateocc" for state occupation probability plots, "entry.norm" / "entry.sub" for normalized / unnormalized state entry time distributions, or "exit.norm" / "exit.sub" for normalized / unnormalized state exit time distributions. "stateocc" is the default.

  ... Further arguments passed to [xyplot](#)

Note

The summary function prints estimates of the transition probabilities P(0,t), state occupation probabilities, and state entry and exit time distributions for each state. Users can explicitly select which information they want to display.

Summary information for the transition probabilities include the event time, estimate of transition probability, variance stimate, lower and upper confidence intervals and the number at risk using methods in Andersen et al. (1993) ("n.risk") and, optionally, the weighted Datta & Satten (2001) estimates ("n.risk.K"). For transitions into a different state, the number of events is also provided according to both methods previously described. For transitions into the same state, the number remaining after the event time is also provided.

Summary information for the state occupation probabilities include the event time, estimate of state occupation probability, variance estimate, and lower and upper confidence intervals.

Estimates for both normalized and non-normalized (sub-distribution) state entry and exit distributions are also displayed.

Author(s)

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References

Nicole Ferguson, Somnath Datta, Guy Brock (2012). msSurv: An R Package for Nonparametric Estimation of Multistate Models. Journal of Statistical Software, 50(14), 1-24. URL http://www.jstatsoft.org/v50/i14/.

Andersen, P.K., Borgan, O., Gill, R.D. and Keiding, N. (1993). Statistical models based on counting processes. Springer Series in Statistics. New York, NY: Springer.

Datta, S. and Satten G.A. (2001). Validity of the Aalen-Johansen estimators of stage occupation probabilities and Nelson-Aalen estimators of integrated transition hazards for non-Markov models. Statistics and Probability Letters, 55(4): 403-411.

Datta S, Satten GA (2002). Estimation of Integrated Transition Hazards and Stage Occupation Probabilities for Non-Markov Systems under Dependent Censoring. Biometrics, 58(4), 792-802.

See Also

For a description of the function `'msSurv'` see `msSurv`.

Examples

```
## 3-state illness-death multistate model (no left-truncation)

## Row data for 3 individuals
## Data in the form "id", "start", "stop", "start.stage", "end.stage"
p1  <- c(1,0,0.21,1,3)
p2  <- c(2,0,0.799,1,2)
p22 <- c(2,0.799,1.577,2,3)
p3  <- c(3,0,0.199,1,0)

## Combining data into a matrix
ex1 <- rbind(p1,p2,p22,p3)
colnames(ex1) <- c("id", "start", "stop", "start.stage", "end.stage")
ex1 <- data.frame(id=ex1[,1], start=ex1[,2], stop=ex1[,3],
                  start.stage=ex1[,4], end.stage=ex1[,5])


## Inputting nodes & edges of the tree structure
Nodes <- c("1","2","3") # states in MSM
Edges <- list("1"=list(edges=c("2","3")),"2"=list(edges=c("3")),
          "3"=list(edges=NULL)) ## allowed transitions between states
                                ## edges=NULL implies terminal node

## Specifying tree
treeobj <- new("graphNEL", nodes=Nodes, edgeL=Edges,
               edgemode="directed")

ans1 <- msSurv(ex1, treeobj)

print(ans1)  ## same as 'show(ans1)'

summary(ans1) ## prints IQR for ans1
summary(ans1, all=TRUE) ## prints all event times for ans1

## prints only state occupation probability info for all event times
summary(ans1, all=TRUE, trans.pr=FALSE, dist=FALSE)

plot(ans1) ## plots state occupation probability
plot(ans1, states="1")
plot(ans1, states=c("1", "2"))
plot(ans1, plot.type="transprob") ## plots for transition probability
```

```
plot(ans1, plot.type="transprob", trans=c("1 2", "1 3"))
```

Pst   *Computation of P(s,t)*

Description

This function calculates the transition probability matrix between any two values s and t and then prints it. The function also calculates and prints the cov(P(s,t)) matrix if the user specifies. Values are returned invisibly.

Usage

```
Pst(object, s=0, t="last", deci=4, covar=FALSE)
```

Arguments

object	An msSurv object.
s	The lower time. Default is 0.
t	The highter time. Default is "last" which is the highest (or "last") event time.
deci	Numeric argument specifying number of decimal places for estimates. Default is 4.
covar	Logical argument to determine if var(P(s,t)) is computed. Default is FALSE.

Details

Computation of P(s,t) and var(P(s,t)) for multistate models are described in Andersen et al. (1993).

Value

Returned invisibly:

Pst The transition probability matrix between two times s and t.

cov.Pst Covariance matrix for the transition probability matrix between two times s and t (if covar==TRUE).

Note

If s = 0 and all subjects begin in the initial state at time 0, then the top row of P(0,t) yields the state occupation probabilities at time t. Data are assumed to follow a Markovian model.

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References

Nicole Ferguson, Somnath Datta, Guy Brock (2012). msSurv: An R Package for Nonparametric Estimation of Multistate Models. Journal of Statistical Software, 50(14), 1-24. URL http://www.jstatsoft.org/v50/i14/.

Andersen, P.K., Borgan, O., Gill, R.D. and Keiding, N. (1993). Statistical models based on counting processes. Springer Series in Statistics. New York, NY: Springer.

See Also

msSurv

Examples

```
## Row elements of data
p1 <- c(1,0,0.21,1,3)
p2 <- c(2,0,0.799,1,2)
p22 <- c(2,0.799,1.577,2,3)
p3 <- c(3,0,0.199,1,0)

## Combining data into a matrix
ex1 <- rbind(p1,p2,p22,p3)
colnames(ex1) <- c("id", "start", "stop", "start.stage", "end.stage")
ex1 <- data.frame(id=ex1[,1], start=ex1[,2], stop=ex1[,3],
                  start.stage=ex1[,4], end.stage=ex1[,5])


## Inputting nodes & edges of the tree structure
Nodes <- c("1","2","3") # states in MSM
Edges <- list("1"=list(edges=c("2","3")),"2"=list(edges=c("3")),
          "3"=list(edges=NULL)) ## allowed transitions between states
                                ## edges=NULL implies terminal node

## Specifying tree
treeobj <- new("graphNEL", nodes=Nodes, edgeL=Edges,
               edgemode="directed")

## Running msSurv
ans1 <- msSurv(ex1,treeobj)
Pst(ans1, s=0.25, t=2.5)
```

RCdata   *Simulated Right Censored Data Set for a 5 State Model*

Description

Simulated data from a five-state progressive model with both branching and tracking between states. Possible transitions are 1->2, 1->3, 2->4, and 2->5, with states 3, 4, and 5 as terminal states.

Usage

```
data(RCdata)
```

Format

A data frame with 1000 individuals with the following 4 variables.

id Identification number

stop Transition time

start.stage State transitioning FROM

end.stage State transitioning TO

Details

A data set of 1000 individuals subject to independent right censoring was simulated, with 60% of individuals starting in state 1 at time 0 and 40% starting in state 2. Those in state 1 remained there until they transitioned to the transient state 2 or the terminal state 3. Individuals in state 2 remained there until they transitioned to either terminal state 4 or 5.

References

Nicole Ferguson, Somnath Datta, Guy Brock (2012). msSurv: An R Package for Nonparametric Estimation of Multistate Models. Journal of Statistical Software, 50(14), 1-24. URL http://www.jstatsoft.org/v50/i14/.

Examples

```
data(RCdata)

#####################################################################
##                  Code used to generate data                    ##
#####################################################################

## Specifying the tree structure for the simulation

Nodes <- c("1", "2", "3", "4", "5") ## states possible in MSM
Edges <- list("1"=list(edges=c("2", "3")), "2"=list(edges=c("4", "5")),
           "3"=list(edges=NULL), "4"=list(edges=NULL), "5"=list(edges=NULL))
RCtree <- new("graphNEL", nodes=Nodes, edgeL=Edges, edgemode="directed")

## Simulating the data
set.seed(123)
n <- 1000
n1 <- 0.6*n
n2<-0.4*n
ill <- round(rweibull(n1, 2), digits=4)
death1 <- round(rweibull(n1, 2), digits=4)
allcensor <- round(rlnorm(n, meanlog=-0.5, sdlog=2), digits=4)
censor<-allcensor[1:n1]
censor2<-allcensor[(1:n2)+length(n1)]
```

```
c1 <- pmin(ill, death1, censor)
num.ill <- sum(ill<death1  & ill<censor) ## number who are "ill"
stage <- ifelse(censor<death1 & censor<ill, 0, ifelse(ill<death1, 2, 3))
data1 <- data.frame(id=1:length(c1), stop=c1, start.stage=1, end.stage=stage)

ind <- which(data1$end.stage==2) ## those transitioning to state 2
## no.st2 <- sum(as.numeric(data1$end.stage==2)) ## number that made transition to 2
death24 <- round(qweibull(pweibull(ill, shape=2) + runif(n1, 0, 1)*
                                (1-pweibull(ill, shape=2)), shape=2), digits=4)

death25 <- round(qweibull(pweibull(ill, shape=2) + runif(n1, 0, 1)*
                                (1-pweibull(ill, shape=2)), shape=2), digits=4)
c2 <- pmin(death24[ind], death25[ind], censor[ind])
stage[ind] <- ifelse(censor[ind]<death24[ind] & censor[ind]<death25[ind], 0,
                     ifelse(death24[ind]<death25[ind], 4, 5))
data2 <- data.frame(id=ind, stop=c2, start.stage=data1$end.stage[ind],
                     end.stage=stage[ind])

death24.2 <- round(rweibull(n2, 2), digits=4)
death25.2 <- round(rweibull(n2, 2), digits=4)
tran<-pmin(death24.2, death25.2, censor2)
stage2 <- ifelse(censor2<death24.2 & censor2<death25.2, 0,
                  ifelse(death24.2<death25.2, 4, 5))
data2.2 <- data.frame(id=(1:n2)+length(c1), stop=tran, start.stage=2, end.stage=stage2)

RCdata <- rbind(data1, data2, data2.2)
RCdata <- RCdata[order(RCdata$id, RCdata$stop), ]
```

SOPt   *State Occupation Probability at Time t*

Description

This function displays the state occupation probability at time t and then prints it. The function also displays the corresponding variance if the user specifies.

Usage

```
SOPt(object, t="last", deci=4, covar=FALSE)
```

Arguments

object	A msSurv object.
t	The time at which we find the state occupation probabilities. Default is "last" which is the highest (or "last") event time.
deci	Numeric argument specifying number of decimal places for estimates. Default is 4.
covar	Logical argument to determine if variance is reported. Default is FALSE.

Details

Displays the state occupation probabilities and corresponding variance for all states in the multistate model.

Value

Returned invisibly:

SOPt The state occupation probability at time t.

var.sop The variance of the state occupation probabilities at time t (if covar==TRUE).

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References

Nicole Ferguson, Somnath Datta, Guy Brock (2012). msSurv: An R Package for Nonparametric Estimation of Multistate Models. Journal of Statistical Software, 50(14), 1-24. URL http://www.jstatsoft.org/v50/i14/.

Datta, S. and Satten G.A. (2001). Validity of the Aalen-Johansen estimators of stage occupation probabilities and Nelson-Aalen estimators of integrated transition hazards for non-Markov models. Statistics and Probability Letters, 55(4): 403-411.

Datta S, Satten GA (2002). Estimation of Integrated Transition Hazards and Stage Occupation Probabilities for Non-Markov Systems under Dependent Censoring. Biometrics, 58(4), 792-802.

See Also

[msSurv](#)

Examples

```
## Row elements of data
p1 <- c(1,0,0.21,1,3)
p2 <- c(2,0,0.799,1,2)
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## Combining data into a matrix
ex1 <- rbind(p1,p2,p22,p3)
colnames(ex1) <- c("id", "start", "stop", "start.stage", "end.stage")
ex1 <- data.frame(id=ex1[,1], start=ex1[,2], stop=ex1[,3],
                  start.stage=ex1[,4], end.stage=ex1[,5])


## Inputting nodes & edges of the tree structure
Nodes <- c("1","2","3") # states in MSM
Edges <- list("1"=list(edges=c("2","3")),"2"=list(edges=c("3")),
          "3"=list(edges=NULL)) ## allowed transitions between states
```

```
                                    ## edges=NULL implies terminal node

## Specifying tree
treeobj <- new("graphNEL", nodes=Nodes, edgeL=Edges,
               edgemode="directed")

## Running msSurv
ans1 <- msSurv(ex1,treeobj)
SOPt(ans1, t=2.5)
```

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