

Package ‘ICBayes’

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Title Bayesian Semiparametric Models for Interval-Censored Data

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Description

Contains functions to fit Bayesian semiparametric regression survival models (proportional hazards model, proportional odds model, and probit model) to interval-censored time-to-event data.

License GPL (>= 2)

LazyLoad yes

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ICBayes-package

Bayesian Semiparametric Models for Interval-Censored Data

Description

This package contains functions to fit several survival regression models (including the proportional hazard model, the proportional odds model, and the probit model) for interval-censored data under Bayesian framework. Estimations are available for both regression coefficients and survival functions. The Bayesian model selection criterion log pseudo marginal likelihood (LPML) is computed.

Details

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Author(s)

Chun Pan, Bo Cai, Lianming Wang, and Xiaoyan Lin

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bcdata

Breast Cosmesis Data

Description

A general interval-censored data set analyzed in Finkelstein and Wolfe (1985) and can be found in Sun (2006, page 7). Early breast cancer patients treated with radiotheraph alone or radiotherapy with adjuvant chemotherapy were examined periodically for breast retraction. Time was measured in months.

Usage

data(bcdata)

Format

A matrix with 96 rows and 4 columns. Each row (L, R, status, x1) corresponds to a patient in the study.

L a numeric vector of left-points of observed time intervals

R a numeric vector of right-points of observed time intervals

status a vector of censorship indicators: 0=left-censored, 1=interval-censored, and 2=right-censored

x1 a vector of treatment indicators: 0=radiotherapy alone, 1=radiotherapy with adjuvant chemotherapy

Source

Finkelstein, D. M. and Wolfe, R. A. (1985). A semiparametric model for regression analysis of interval-censored failure time data. *Biometrics* **41** 933-945.

Sun, J. (2006). *The Statistical Analysis of Interval-censored Failure Time Data*. Springer, New York.

Examples

```
data(bcdata)
```

```
case1ph
```

```
PH model for case 1 interval-censored data
```

Description

Fit proportional hazards model for case 1 interval-censored data. Use MCMC method to estimate regression coefficients, baseline survival, and survival at user-specified covariate values.

Usage

```
case1ph(L, R, status, xcov, x_user, order, sig0, coef_range,
a_eta, b_eta, knots, grids, niter, seed)
```

Arguments

L	a numeric vector of left timepoints of observed time intervals.
R	a numeric vector of right timepoints of observed time intervals.
status	a vector of censoring indicators: 1=left-censored, 0=right-censored.
xcov	a matrix of covariates, each column corresponds to one covariate.
x_user	a user specified vector of covariate values
order	degree of I-splines (b_1) (see details). Recommended values are 2-4.
sig0	standard deviation of normal prior for each regression coefficient beta_r.

coef_range	specify support domain of target density for beta_r sampled by arms (see details).
a_eta	shape parameter of Gamma prior for gamma_l (see details).
b_eta	rate parameter of Gamma prior for gamma_l (see details).
knots	a sequence of points to define I-splines.
grids	a sequence of points where baseline survival function is to be estimated.
niter	total number of iterations of MCMC chains.
seed	a user specified random seed, default is NULL.

Details

The baseline cumulative hazard is approximated by a linear combination of I-splines:

$$\sum_{l=1}^k (\gamma_l * b_l).$$

Function [arms](#) is used to sample each regression coefficient beta_r, and coef_range specifies the support of the indFunc in [arms](#).

Value

a list containing the following elements:

parbeta	a niter by p matrix of MCMC draws of beta_r, r=1, ..., p.
parsurv0	a niter by length(grids) matrix, each row contains the baseline survival at grids from one iteration.
parsurv	a niter by length(grids)*G matrix, each row contains the survival at grids from one iteration. G is the number of sets of user-specified covariate values.
parfinv	a niter by n matrix, each row contains the inverse PDF of observed interval-censored data from one iteration. This is used for computing LPML later.
grids	a sequence of points where baseline survival is estimated.

Author(s)

Bo Cai

References

Cai, B., Lin, X., and Wang, L. (2011). Bayesian proportional hazards model for current status data with monotone splines. *Computational Statistics and Data Analysis*, **55** 2644-2651.

 case1po

PO model for case 1 interval-censored data

Description

Fit proportional odds model for case 1 interval-censored data. Use MCMC method to estimate regression coefficients, baseline survival, and survival function at user-specified covariate values.

Usage

```
case1po(L, R, status, xcov, x_user, order, sig0, coef_range,
a_eta, b_eta, knots, grids, niter, seed)
```

Arguments

L	a numeric vector of left timepoints of observed time intervals.
R	a numeric vector of right timepoints of observed time intervals.
status	a vector of censoring indicators: 1=left-censored, 0=right-censored.
xcov	a matrix of covariates, each column corresponds to one covariate.
x_user	a vector of user specified covariate values.
order	degree of I-splines (b_1) (see details). Recommended values are 2-4.
sig0	standard deviation of normal prior for each regression coefficient beta_r.
coef_range	specify support domain of target density for beta_r sampled by arms (see details).
a_eta	shape parameter of Gamma prior for gamma_1 (see details).
b_eta	rate parameter of Gamma prior for gamma_1 (see details).
knots	a sequence of points to define I-splines.
grids	a sequence of points where baseline survival function is to be estimated.
niter	total number of iterations of MCMC chains.
seed	a user specified random seed, default is NULL.

Details

The baseline odds function is approximated by a linear combination of I-splines:

$$\sum_{l=1}^k (\gamma_l * b_l).$$

Function [arms](#) is used to sample each regression coefficient beta_r, and coef_range specifies the support of the indFunc in [arms](#).

Value

a list containing the following elements:

parbeta	a niter by p matrix of MCMC draws of β_r , $r=1, \dots, p$.
parsurv0	a niter by $\text{length}(\text{grids})$ matrix, each row contains the baseline survival at grids from one iteration.
parsurv	a niter by $\text{length}(\text{grids}) \times G$ matrix, each row contains the survival at grids from one iteration. G is the number of sets of user-specified covariate values.
parfinv	a niter by n matrix, each row contains the inverse PDF of observed interval-censored data from one iteration. This is used for computing LPML later.

Author(s)

Xiaoyan Lin

References

Lin, X. and Wang, L. (2011). Bayesian proportional odds model for analyzing current status data: univariate, clustered, and multivariate. *Communication in Statistics-Simulation and Computation*, **40** 1171-1181.

case2ph

PH model for general interval-censored data

Description

Fit proportional hazards model for general interval-censored data. Use MCMC method to estimate regression coefficients, baseline survival, and survival function at user-specified covariate values.

Usage

```
case2ph(L, R, status, xcov, x_user, order, sig0, coef_range,
a_eta, b_eta, knots, grids, niter, seed)
```

Arguments

L	a numeric vector of left timepoints of observed time intervals.
R	a numeric vector of right timepoints of observed time intervals.
status	a vector of censoring indicators: 1=left-censored, 0=right-censored.
xcov	a matrix of covariates, each column corresponds to one covariate.
x_user	a user specified vector of covariate values.
order	degree of I-splines (b_1) (see details). Recommended values are 2-4.
sig0	standard deviation of normal prior for each regression coefficient β_r .
coef_range	specify support domain of target density for β_r sampled by arms (see details).

a_eta	shape parameter of Gamma prior for gamma_1 (see details).
b_eta	rate parameter of Gamma prior for gamma_1 (see details).
knots	a sequence of points to define I-splines.
grids	a sequence of points where baseline survival function is to be estimated.
niter	total number of iterations of MCMC chains.
seed	a user specified random seed, default is NULL.

Details

The baseline cumulative hazard is modeled by a linear combination of I-splines:

$$\sum_{l=1}^k (\gamma_l * b_l).$$

Function [arms](#) is used to sample each regression coefficient beta_r, and coef_range specifies the support of the indFunc in [arms](#).

Value

a list containing the following elements:

parbeta	a niter by p matrix of MCMC draws of beta_r, r=1, ..., p.
parsurv0	a niter by length(grids) matrix, each row contains the baseline survival at grids from one iteration.
parsurv	a niter by length(grids)*G matrix, each row contains the survival at grids from one iteration. G is the number of sets of user-specified covariate values.
parfinv	a niter by n matrix, each row contains the inverse PDF of observed interval-censored data from one iteration. This is used for computing LPML later.
grids	a sequence of points where baseline survival is estimated.

Author(s)

Bo Cai

References

Lin, X., Cai, B., Wang, L., and Zhang, Z. (2015). Bayesian proportional hazards model for general interval-censored data. *Lifetime Data Analysis*, **21** 470-490.

 case2probit

Probit model for general interval-censored data

Description

Fit probit model to general interval-censored data. Use MCMC method to estimate regression coefficients, baseline survival, and survival function at user-specified covariate values.

Usage

```
case2probit(L, R, status, xcov, x_user, order,
            v0, a_eta, b_eta, knots, grids, niter, seed)
```

Arguments

L	a numeric vector of left timepoints of observed time intervals.
R	a numeric vector of right timepoints of observed time intervals.
status	a vector of censoring indicators: 0=left-censored, 1=interval-censored, 2=right-censored.
xcov	a matrix of covariates, each column corresponds to one covariate.
x_user	a vector of user specified covariate values.
order	degree of I-splines (b_1) (see details). Recommended values are 2-4.
v0	precision of normal prior for gamma_0.
a_eta	shape parameter of Gamma prior for gamma_1 (see details).
b_eta	rate parameter of Gamma prior for gamma_1 (see details).
knots	a sequence of points to define I-splines.
grids	a sequence of points where baseline survival function is to be estimated. Default is minimum observed time points.
niter	total number of iterations of MCMC chains.
seed	a user specified random seed, default is NULL.

Details

The baseline function is modeled by a linear combination of I-splines:

$$\text{gamma}_0 + \sum_{l=1}^k \text{gamma}_l * \text{b}_l.$$

Regression coefficient vector beta is sampled from a multivariate normal distribution. For more information, please see reference.

Value

a list containing the following elements:

parbeta	a niter by p matrix of MCMC draws of beta_r, r=1, ..., p.
parsurv0	a niter by length(grids) matrix, each row contains the baseline survival at grids from one iteration.
parsurv	a niter by length(grids)*G matrix, each row contains the survival at grids from one iteration. G is the number of sets of user-specified covariate values.
parfinv	a niter by n matrix, each row contains the inverse PDF of observed interval-censored data from one iteration. This is used for computing LPML later.
grids	a sequence of points where baseline survival is estimated.

Author(s)

Lianming Wang and Xiaoyan Lin. R version by Bo Cai.

References

Lin, X. and Wang, L. (2009). A semiparametric probit model for case 2 interval-censored failure time data. *Statistics in Medicine* **29** 972-981.

coef.ICBayes	<i>coef method for class ICBayes</i>
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Description

extracts estimated regression coefficient(s)

Usage

```
## S3 method for class 'ICBayes'
coef(object, ...)
```

Arguments

object	class ICBayes object
...	other arguments if any

Value

a scalar or vector

ICBayes

*PH, PO, and Probit Models for Interval-Censored Data***Description**

Calls the `case1ph`, `case2ph`, or `case2probit` function to fit the corresponding model. Give point estimates and credible intervals for regression coefficients and estimation and plot of survival functions.

Usage

```
ICBayes(L, ...)

## Default S3 method:
ICBayes(L, R, model, status, xcov, x_user=NULL, order=2,
sig0=10, coef_range=5, v0=0.1, a_eta=1, b_eta=1,
knots=NULL, grids=NULL, conf.int=0.95,
niter=5000, burnin=1000, thin=1, seed=NULL, ...)
## S3 method for class 'formula'
ICBayes(formula, data, ...)
```

Arguments

L	a column vector of left-points of observed time intervals.
R	a column vector of right-points of observed time intervals. Use NA to denote infinity.
model	a character string specifying the type of model. Possible values are "case1ph", "case2ph", "case2po", and "case2probit".
status	a vector of censoring indicators. If <code>model="case1ph"</code> , then 1=left-censored, 0=right-censored. If <code>model="case2ph"</code> , "case2po", or "case2probit", then 0=left-censored, 1=interval-censored, 2=right-censored.
xcov	a matrix of covariates, each column corresponds to one covariate.
x_user	a vector of covariate values, default is NULL. Need to specify for survival estimation.
order	degree of I-splines (<code>b_1</code>) (see details). Recommended values are 2-4. Default is 2.
sig0	standard deviation of normal prior for each regression coefficient <code>beta_r</code> . Used if <code>model="case1ph"</code> , "case1po", or "case2ph". Default is 10.
coef_range	specify support domain of target density for <code>beta_r</code> using <code>arms</code> (see details). Used if <code>model="case1ph"</code> , "case1po", or "case2ph". Default is 5.
v0	precision of normal prior for <code>gamma_0</code> . Used if <code>model="case2po"</code> or "case2probit". Default is 0.1.
a_eta	shape parameter of Gamma prior for <code>gamma_1</code> (see details). Default is 1.
b_eta	rate parameter of Gamma prior for <code>gamma_1</code> (see details). Default is 1.

knots	a sequence of points to define I-splines. Default is a sequence of time points from min to max with length=10.
grids	a sequence of points where survival function is to be estimated. Default is a sequence of time points from min to max with length=100.
conf.int	level for a two-sided credible interval on coefficient estimate(s). Default is 0.95.
niter	total number of iterations of MCMC chains. Default is 11000.
burnin	number of iterations to discard at the beginning of an MCMC run. Default is 1000.
thin	specify thinning of MCMC draws. Default is 1.
seed	a use-specified random seed. Default is NULL.
formula	a symbolic description of the model to be fit.
data	a data frame containing the variables in the model.
...	values passed to other functions.

Details

For "case1ph", "case1po", and "case2ph" models, function `arms` is used to sample regression coefficient β_r , and `coef_range` specifies the support of the `indFunc` in `arms`. The baseline cumulative hazard in "case1ph" and "case2ph" models and the baseline odds function in "case1po" are modeled by a linear combination of I-splines:

$$\sum_{l=1}^k (\gamma_l * b_l).$$

For "case2probit" model, baseline function is modeled by a linear combination of I-splines:

$$\gamma_0 + \sum_{l=1}^k (\gamma_l * b_l).$$

For "case2probit" model, regression coefficient vector β is sampled from a multivariate normal distribution.

For more information, please see reference.

Value

an object of class `ICBayes` containing the following elements:

<code>coef</code>	a vector of regression coefficient estimates
<code>coef_ssd</code>	a vector of sample standard deviations of regression coefficient estimates
<code>coef_ci</code>	credible intervals for regression coefficients
<code>LPML</code>	log pseudo marginal likelihood for model selection, the larger the better
<code>grids</code>	the sequence of points where baseline survival functions is estimated
<code>S0_m</code>	estimated baseline survival probabilities at <code>grids</code>
<code>S_m</code>	a $\text{length}(\text{grids}) * G$ by 2 matrix that contains estimated survival probabilities at <code>grids</code> for <code>x_user</code> , where G is the number of sets of covariate values
<code>S_ci</code>	credible intervals for survival probabilities at <code>grids</code> for <code>x_user</code>
<code>mcmc_beta</code>	a <code>niter</code> by p matrix of mcmc chains for regression coefficients, where <code>niter</code> is the number of iterations and p is the number of covariates
<code>mcmc_surv</code>	a <code>niter</code> by $\text{length}\{\text{grids}\} * G$ matrix of mcmc chains for survival probabilities at <code>grids</code> , where <code>niter</code> is the number of iterations and G is the number of sets of covariate values

Author(s)

Chun Pan

References

Cai, B., Lin, X., and Wang, L. (2011). Bayesian proportional hazards model for current status data with monotone splines. *Computational Statistics and Data Analysis*, **55** 2644-2651.

Lin, X. and Wang, L. (2009). A semiparametric probit model for case 2 interval-censored failure time data. *Statistics in Medicine*, **29** 972-981.

Lin, X. and Wang, L. (2011). Bayesian proportional odds model for analyzing current status data: univariate, clustered, and multivariate. *Communication in Statistics-Simulation and Computation*, **40** 1171-1181.

Lin, X., Cai, B., Wang, L., and Zhang, Z. (submitted). Bayesian proportional hazards model for general interval-censored data.

See Also

[case1ph](#), [case1po](#), [case2ph](#), [case2probit](#)

Examples

```
# To save time in checking package, niter is set to only 500 iterations.
# formula form
data(bcdata)
bcdata<-data.frame(bcdata) # must be a data frame
try<-ICBayes(Surv(L,R,type='interval2')~x1,data=bcdata,
model='case2ph',status=bcdata[,3],x_user=c(0,1),knots=seq(0.1,60.1,length=10),
grids=seq(0.1,60.1,by=1),niter=500,burnin=100)
# general form
try2<-ICBayes(model='case2ph',L=bcdata[,1],R=bcdata[,2],status=bcdata[,3],
xcov=bcdata[,4],x_user=c(0,1),knots=seq(0.1,60.1,length=10),
grids=seq(0.1,60.1,by=1),niter=500,burnin=100)
```

logLik.ICBayes

logLik method for class ICBayes

Description

log-likelihood of the observed interval-censored data estimated by log pseudo marginal likelihood

Usage

```
## S3 method for class 'ICBayes'
logLik(object, ...)
```

Arguments

object class ICBayes object
... other arguments if any

Value

a scalar

lungdata

Lung cancer data

Description

A case 1 interval-censored data set first presented in Hoel and Walberg (1972) and can be found in Sun (2006, page 6). In the study, 144 male RFM mice were raised under two conditions: conventional environment (96 mice) and germfree environment (48 mice). Each mouse was "sacrificed" at a random time to see if it had lung tumors. Time was measured in days.

Usage

```
data(lungdata)
```

Format

A matrix with 144 rows and 4 columns. Each row (L, R, status, treatment) corresponds to a mouse in the study.

L left-points of observed intervals

R right-points of observed intervals

status censorship indicator: 1=left-censor and 0=right-censor

treatment treatment indicator: 1=conventional environment, 2=germfree environment

Source

Hoel, D. G. and Walberg, H. E. (1972). Statistical analysis of survival experiments. *Journal of the National Cancer Institute* **49** 361-372.

Sun, J. (2006). *The Statistical Analysis of Interval-censored Failure Time Data*. Springer, New York.

Examples

```
data(lungdata)
```

plot.ICBayes	<i>Plot baseline survival function</i>
--------------	--

Description

Plot estimated baseline survival function at grids, which are stored in the ICBayes object.

Usage

```
## S3 method for class 'ICBayes'
plot(x, y, ...)
```

Arguments

x	a sequence of points where baseline survival probabilities are estimated
y	estimated baseline survival at grids
...	other arguments

Value

A plot of baseline survival function.

Examples

```
data(bcdata)
try<-ICBayes(Surv(L,R,type='interval2')~x1,data=data.frame(bcdata),
model='case2ph',status=bcdata[,3],p=1,x_user=c(1),
knots=seq(0.1,60.1,length=10),grids=seq(0.1,60.1,by=1),niter=500,burnin=100)
plot.ICBayes(try$grids,try$S0_m)
```

summary.ICBayes	<i>summary method for class ICBayes</i>
-----------------	---

Description

present output from function [ICBayes](#)

Usage

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

Arguments

object	class ICBayes object
...	other arguments if any

Value

an object of class ICBayes containing the following elements

coef	a named vector of coefficient estimates
coef_ssd	a named vector of sample standard deviations of coefficient estimates
coef_ci	a named matrix of credible intervals for coefficients
LPML	log pseudo marginal likelihood

SurvtoLR

Transform Surv object to data matrix with L and R columns

Description

Take a [Surv](#) object and transforms it into a data matrix with two columns, L and R, representing the left and right points of observed time intervals. For right-censored data, R = NA.

Usage

```
SurvtoLR(x)
```

Arguments

x a [Surv](#) object

Details

The input Surv object should be in the form of `Surv(L, R, type='interval2')`, where R = NA for right-censored data.

Value

A data matrix with two variables:

L	left-points of observed time intervals
R	right-points of observed time intervals

References

Michael P. Fay, Pamela A. Shaw (2010). Exact and Asymptotic Weighted Logrank Tests for Interval Censored Data: The interval R Package. *Journal of Statistical Software*, **36** 1-34.

Examples

```
library(survival)
L<-c(45,6,0,46)
R<-c(NA,10,7,NA)
y<-Surv(L,R,type='interval2')
SurvtoLR(y)
```

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