

Package ‘RLadyBug’

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Title Analysis of Infectious Diseases using Stochastic Epidemic Models

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Imports graphics, stats, grDevices, utils, MASS, boa, quadprog

Description The package consists of two independent tools to analyse infectious disease surveillance data: 1. Stochastic Susceptible-Exposed-Infectious-Recovered (SEIR) models are treated by the java program LadyBug, i.e. for use of this functionality of the package a java virtual machine has to be installed on your computer. 2. Multivariate temporal counting processes for a fixed set of locations are modeled through additive-multiplicative conditional intensities (fitted by the ‘twinSIR’ function).

License file LICENSE

URL <http://www.stat.uni-muenchen.de/~hoehle/software/RLadyBug>

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RLadyBug-package	<i>Analysis of infectious diseases using stochastic epidemic models</i>
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Description

RLadyBug is an S4-package for the simulation, visualization and estimation of stochastic epidemic models in R. Utilizing the Susceptible-Infected-Recovered (SIR) and the S-Exposed-IR (SEIR) model as mathematical framework, maximum likelihood and Bayesian inference can be performed to estimate the parameters in data from a single outbreak of an infectious disease typical in e.g. disease transmission experiments. As of version 0.5 the package can also perform SIR modelling of infectious disease surveillance data containing several outbreaks.

Details

Package: RLadyBug
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License: GPL version 2 (<http://www.gnu.org/licenses/gpl.html>)

- Likelihood and Bayesian inference for the SEIR-modelling of a single outbreak in a heterogeneous population as in Höhle et al. (2005) using an additive intensity model. Typical examples are animal disease transmission experiments. Event observations can be missing.
- Analysis of the same type of data structure based on approximate inference using Poisson regression as in Klinkenberg et al. (2002)
- Likelihood based analysis of infectious disease surveillance data using a model containing endemic and epidemic components in a counting process framework (Höhle, 2008). The endemic component can be modelled through covariates.

The aim of the package is to take a step towards statistical software supporting parameter estimation, the calculation of confidence intervals and hypothesis testing for stochastic epidemic models.

Author(s)

Michael Höhle, Ulrike Feldmann and Sebastian Meyer

Maintainer: Michael Höhle <<hoehle@stat.uni-muenchen.de>>

References

RLadyBug – An R package for working with stochastic epidemic models (2007), M. Höhle and U. Feldmann, *Computational Statistics and Data Analysis*, 52(2), pp. 680–686.

Höhle, M. (2008) Spatio-temporal epidemic modelling using additive-multiplicative intensity models. *Ludwig-Maximilians-Universität, Department of Statistics: Technical Reports*, No. 41. Available at <http://epub.ub.uni-muenchen.de/6366/>.

Höhle, M., Jørgensen, E. and O’Neill, P.D. (2005), *Journal of the Royal Statistical Society, Series C*, 54(2), pp. 349–366.

Klinkenberg, D., De Bree, J., Laevens, H. and De Jong, M. C. M. (2002), Within- and between-pen transmission of Classical Swine Fever Virus: a new method to estimate the basic reproduction ratio from transmission experiments, *Epidemiol. Infect.*, 128, 293-299.

Examples

```
## Not run: demo(article-csda)
```

abakaliki

Smallpox epidemic in Abakaliki, Nigeria

Description

Use MCMC to estimate parameters in the smallpox epidemic of Abakaliki, Nigeria also treated in the article by O'Neill and Roberts.

Usage

```
data(abakaliki)
```

Source

O'Neill, P. D. and Roberts, G. O. (1999). Bayesian inference for partially observed stochastic epidemics. *J. R. Statist. Soc. A* 162, 121–129.

Examples

```
## Not run: data(abakaliki)
## Not run: seir(abakaliki,abakaliki.opts)
```

animate

Generic animation of spatio-temporal objects

Description

Generic function for animation of R objects.

Usage

```
animate(object, ...)
```

Arguments

object	The object to animate.
...	Arguments to be passed to methods, such as graphical parameters or time interval options for the snapshots.

See Also

The methods [animate.epidata](#) for the animation of epidemics.

`csfv`*CSFV Transmission Experiment*

Description

Analysis of the transmission rates in the classical swine fever virus transmission experiment in the Dewulf et al. (2001) article.

Usage

```
data(csfv)
```

Details

The `csfvML` dataset is a version of `csfv`, where the exposure time is specified with an artificially assumed fixed incubation time of 6 days, except for the inoculated individual which has an incubation time of three days. This is rather ad hoc but allows us to calculate ML estimates.

The `csfvTDprior` dataset is a version of `csfv`, where rather strong priori distributions are assumed for the waiting time from exposure until diagnosis.

Note that respective `csfv.opts`, `csfvML.opts` and `csfvTD.opts` objects are loaded which provide an appropriate estimation method.

Source

An experimental infection with classical swine fever in E2 sub-unit marker-vaccine vaccinated and in non-vaccinated pigs, Vaccine 19, pages 475-482.

Examples

```
## Not run: data(csfv)
## Not run: seir(csfv,csfv.opts)
```

`hksars`*Hong Kong SARS outbreak 2003*

Description

Severe Acute Respiratory Syndrome (SARS) data from the 2003 outbreak in Hong Kong. Data contain the daily reported number of cases among health care and others as given in Figure 2 of Anonymous (2003). A susceptible population of 6.7 mio is assumed.

Usage

```
data("hksars")
```

Details

A constant incubation time of 6.4 days and a constant recovery time of 34 days as in Donnelly et al. (2003) is assumed. Figure 2 in Anonymous (2003) provides the exposure time. A homogenous population is assumed.

Source

Anonymous (2003). Sars bulletin. Technical report, Health, Welfare and Food Bureau, Government of the Hong Kong Special Administrative Region, 10 June 2003. Available as <http://www.info.gov.hk/info/sars/bulletin/bulletin0610e.pdf>

Donnelly, C. A., Ghani, A. C., Leung, G. M., and 16 more authors (2003). Epidemiological determinants of spread of causal agent of severe acute respiratory syndrome in Hong Kong. *The Lancet*, 361:1761

Examples

```
data("hksars")

## Not run:
#Show how to plot using EpiTools
require("epitools")
require("chron")

E <- chron("2/15/2003") + hksars@data$E
curve <- epicurve.dates(E,axisnames = FALSE,before=0, after=0,legend.text = TRUE,col = colorbrewer.palette(3, "seq")
axis(1, at = curve$xvals, labels = curve$cmday, tick = FALSE, line = 0)
axis(1, at = curve$xvals, labels = curve$cmmonth, tick = FALSE, line = 1)

## End(Not run)
```

ladybugExample

Access files in the LadyBug directory examples directory

Description

A small helper function to access files in the LadyBug *examples/* directory.

Usage

```
ladybugExample(exp.file)
```

Arguments

exp.file The filename relative to <LADYBUG>/examples/

Value

The complete filename, where <LADYBUG> is replaced by options("ladybugPath").

Author(s)

M. Höhle

Examples

```
## Not run: ladybugExample( "/csfv/mcmc.sir" )
```

laevens

*CSFV Experiment by Laevens et. al***Description**

In this experiment the spread of CSFV was investigated in a 1×3 layout with $S(0) = (5, 5, 6)$ and $E(0) = (0, 1, 0)$ slaughter pigs. Every second day all pigs still alive were investigated using a virus isolation test based on blood plasma.

Usage

```
data(laevens)
```

Format

The format is:

```
Formal class 'LBExperiment' [package "RLadyBug"] with 2 slots
..@ data :'data.frame': 15 obs. of 6 variables:
.. ..$ x: int [1:15] 1 1 1 1 1 1 1 1 1 1 ...
.. ..$ y: int [1:15] 2 1 1 1 1 2 2 2 2 3 ...
.. ..$ E: int [1:15] 0 18 14 20 20 10 10 10 6 20 ...
.. ..$ I: int [1:15] 6 24 20 26 26 16 16 16 12 26 ...
.. ..$ R: int [1:15] 12 34 28 34 34 32 34 28 30 28 ...
.. ..$ D: int [1:15] 12 34 28 34 34 32 34 28 30 28 ...
..@ layout:Formal class 'LBLAYOUT' [package "RLadyBug"] with 2 slots
.. .. ..@ S0: num [1, 1:3] 5 5 6
.. .. ..@ E0: num [1, 1:3] 0 1 0
```

Details

Together with an object `laevens` also an object `laevens.opts` is loaded which is an object of class [LBInferenceMCMC-class](#) suitable for MCMC inference

The `data(laevensML)` contains a version of the data, where a constant incubation time of $c=6$ is assumed. Here `laevens.opts` contains the necessary object for maximum likelihood inference.

Source

H. Laevens, F. Koenen, H. Deluyker and A. de Kruif, Experimental infection of slaughter pigs with classical swine fever virus: transmission of the virus, course of the disease and antibody response, *Vet. Rec.*, 1999, 145:243-248.

Examples

```
data(laevens)
```

```
LBExperiment-class    Class "LBExperiment"
```

Description

S4 class containing the data and the layout of the infectious disease data

Slots

data: Data Frame with six columns: x, y, E, I, R, D

layout: Object of class "LLayout"

T: A "numeric" specifying how long the epidemic was observed.

Methods

data2events signature(object = "LBExperiment"): convert the data.frame of events for each individual to a time order data.frame of events for the entire Experiment. The information about each individual is lost. This function is used internally.

show signature(object = "LBExperiment"): shows all slots of the LBExperiment object.

setLayout<- signature(object = "LBExperiment"): sets the Layout.

plot signature(signature(x="LBExperiment", y="missing"), function(x, y, type=NULL, options=NULL, ...)) The type argument should be a formula specifying the desired type of plot. By providing an additional options list individual parameters for the plots are provided. Valid formulae are

`state ~ time | position` The number of susceptible, infectious and recovered as a function of time for each unit. Warning: in case there are many units this plot might be rather useless.

`state ~ time` shows the total number of susceptible, infectious and recovered (i.e. summed over all units) as a function of time. Individual options are `stacked` boolean whether stacked boxplots or just time-series are shown.

`state ~ 1|position` illustrates the three multivariate time series (susceptible, exposed, infected) as a "film" with `noOfPics` pictures. Individual options are `chart` Either "pie" or "bar", where the latter is default.

`justInf` if FALSE pie charts with the number of S(t),E(t),I(t) are shown, otherwise only the number of infectious is shown, where the radius shows the proportion.

`noOfPics` How many pictures in the animation. If not saved set the "History" attribute of the X11.

`PDF` If TRUE the results are saved in PDF Files with the base name `name`.

`name` Base name of the generated PDF Files. The actual files are then names `name-addstr-number.pdf`

addstr This is added to the base name.
 individual ~ time shows all events for each individual
 individual ~ time | **position** show individual histories of each individual aligned to the same time axis
 Additional parameters to the underlying plot routine, e.g. xlab, legend=FALSE, color, are passed using

Examples

```
sim.layout <- new( "LBLayout", S0=matrix( c( 13, rep( 14, 7 ) ), ncol=4 ),
                 E0=matrix( c( 1, rep( 0, 7 ) ), ncol=4 ) )
sim.opts <- new( "LBOptions", seed=2006,
                LBmodel=c( "gamma", "gamma", "gamma", FALSE ),
                ignoreData=c( FALSE, FALSE, FALSE ),
                initBeta =list( init=0.125,
                                gamma=0.001, delta=0.001 ),
                initBetaN=list( init=0.018,
                                gamma=0.001, delta=0.001 ),
                initIncu=list( asis=FALSE, const=FALSE,
                                g=6.697, g.gamma=0.001, g.delta=0.001,
                                d=0.84, d.gamma=0.001,d.delta=0.001 ),
                initInf=list( 1.772, 0.001, 0.001, 0.123, 0.001, 0.001 ),
                initDia=list( 149.126, 0.001, 0.001,
                                8.737, 0.001, 0.001 ) )
exp <- simulate( sim.opts, layout=sim.layout )
plot(exp,type = state ~ time)
plot(exp,type = state ~ time, options=list(stacked=FALSE))
```

LBInference-class *Class "LBInference" – captures results for SEIR inference*

Description

This class contains results from inference by the LadyBug program.

Objects from the Class

Usually, there is no need to create objects of this class by hand.

Slots

paramHat: Object of class "numeric" A vector with point estimates for the model parameters.

paramSe: Object of class "numeric" Point estimates for the standard error.

aic: Object of class "numeric" Akaikes Information Criterion.

loglik: Object of class "numeric" Value of the log likelihood.

Methods

infValues signature(object = "LBInference"): Fetches a list with all slots.
infValues<- signature(object = "LBInference"): ...
show signature(object = "LBInference"): ...
summary signature(object = "LBInference"): ...

See Also

[LBInferenceML-class](#) and [LBInferenceMCMC-class](#)

Examples

```
data(oneill)
mcmc <- seir(oneill,oneill.opts)
## Not run: infValues(mcmc)
```

LBInferenceMCMC-class *Class "LBInferenceMCMC" – results from MCMC inference in SEIR models*

Description

This class holds the results from MCMC inference for SEIR models, i.e. sample paths and provides routines to calculate R_0

Objects from the Class

Objects can be created by calls of the form `new("LBInferenceMCMC", paramHat, paramSe, aic, loglik, samplePaths)`.

Slots

samplePaths: Object of class "data.frame" A data frame containing the va
paramHat: Object of class "numeric" ~~
paramSe: Object of class "numeric" ~~
aic: Object of class "numeric" ~~
loglik: Object of class "numeric" ~~

Extends

Class "LBInference", directly.

Methods

infValues signature(object = "LBInferenceMCMC"): ...

infValues<- signature(object = "LBInferenceMCMC"): ...

initialize signature(.Object = "LBInferenceMCMC"): ...

plot signature(x = "LBInferenceMCMC", y = "missing"): Important is the which argument
 "beta" CODA diagnostics for the β parameter
 "betabetaN" Provides a diagnostic plot and HPD interval for the $\frac{\beta}{\beta_n}$ ratio.

R0 signature(object = "LBInferenceMCMC"): Compute the basic reproduction ratio for each sample. Mean, median, etc. are then computed.

samplePaths signature(object = "LBInferenceMCMC"): get the sample paths

show signature(object = "LBInferenceMCMC"): as usual

summary signature(object = "LBInferenceMCMC"): as usual

See Also

[LBInference-class](#)

Examples

```
#Load Laevens (99) data
data(laevens)
inf.mcmc <- seir(laevens,laevens.opts)
#Algo part of the Options
algo(laevens.opts)

#Results
inf.mcmc

#Analysis through coda (library coda is called when starting RLadyBug)
samples <- mcmc(samplePaths(inf.mcmc))
plot(samples[, "beta"])

#Look at the \beta/\beta_n ratio
ratio <- plot(inf.mcmc, which = "betabetaN")
c(mean=ratio$mean, ratio$hpd)

#R0
quantile(R0(inf.mcmc, laevens), c(0.025, 0.5, 0.975))
```

LBInferenceML-class *Class "LBInferenceML" – results from ML inference in SEIR models*

Description

Results from a maximum likelihood inference in SEIR models

Objects from the Class

Objects can be created by calls of the form `new("LBInferenceML", ...)`. ~~ describe objects here ~~

Slots

`cov`: Object of class "matrix" giving the covariance matrix of all parameters, i.e. this is the inverse negative Hessian matrix evaluated at the MLE.

`corr`: Object of class "numeric" ~~

`paramHat`: Object of class "numeric" containing the MLE of all parameters~

`paramSe`: Object of class "numeric" containing the standard error of all parameters

`aic`: Object of class "numeric" AIC of the fitted model

`loglik`: Object of class "numeric" containing the loglik at the MLE

Extends

Class "LBInference", directly.

Methods

infValues signature(object = "LBInferenceML"): get all slots

infValues<- signature(object = "LBInferenceML"): set a list of slots

show signature(object = "LBInferenceML"): as usual

summary signature(object = "LBInferenceML"): as usual

R0 signature(object = "LBInferenceML"): Compute the basic reproduction ratio based on the largest eigenvalue of the transmission matrix.

See Also

[LBInference-class](#)

Examples

```
data(laevensML)
seir(laevensML, laevensML.opts)
```

LBInferenceMLK-class *Class "LBInferenceMLK" – results from MLK inference in SEIR models*

Description

Results from the Klinkenberg inference method

Objects from the Class

Objects can be created by calls of the form `new("LBInferenceMLK", ...)`. `~~` describe objects here `~~`

Slots

`r0`: Object of class "numeric"
`r0.ci`: Object of class "numeric" containing the confidence interval of `r0`
`cov`: Object of class "matrix" giving the covariance matrix of all parameters, i.e. this is the inverse negative Hessian matrix evaluated at the MLE.
`corr`: Object of class "numeric" `~~`
`paramHat`: Object of class "numeric" containing the MLE of all parameters
`paramSe`: Object of class "numeric" containing the standard error of all parameters
`aic`: Object of class "numeric" AIC of the fitted model
`loglik`: Object of class "numeric" containing the loglik at the MLE

Extends

Class "LBInferenceML", directly.

Methods

infValues signature(object = "LBInferenceMLK"): get all slots
infValues<- signature(object = "LBInferenceMLK"): set a list of slots
show signature(object = "LBInferenceMLK"): as usual
summary signature(object = "LBInferenceMLK"): as usual

See Also

[LBInferenceML-class](#)

LLayout-class *Class "LLayout" – grid layout structure*

Description

This class is used to specify the spatial (or structural) arrangement of the populations. Currently only a grid layout is handled.

Objects from the Class

Objects can be created by calls of the form `new("LLayout", ...)`.

Slots

S0: Object of class "matrix" A matrix specifying the number of initially susceptible in each unit.

E0: Object of class "matrix" A matrix specifying the number of initially exposed in each unit.

Methods

layoutAsDataFrame signature(object = "LLayout"): Returns a data frame containing the columns "u", "x", "y", "S" and "E"

layoutMatrixes signature(object = "LLayout"): provides a list with S0 and E0 in matrix form

show signature(object = "LLayout"): as usual

summary signature(object = "LLayout"): as usual

Note

Currently, LadyBug is not able to handle more than one initially exposed. This will change in the near future.

See Also

See also [LBExperiment-class](#).

Examples

```
data(csfv)
```

LBOptions-class *Class "LBOptions"*

Description

Specification of LadyBug SEIR models

Objects from the Class

Objects can be created by calls of the form `new("LBOptions", seed, LBmodel, ignoreData, initBeta, initBetaN, initIncu, initInf, initDia, algo, randomWalk)`.

Slots

seed: Object of class "numeric" The seed value to use when calling the Java program

LBmodel: Object of class "vector" Contains a specification of the SEIR model, i.e. a vector with names

<code>incuTimePDF</code>	distribution of incubation time
<code>infTimePDF</code>	distribution of the infectious time
<code>diagTimePDF</code>	distribution of the seroconversion time
<code>meanVar</code>	mean variance representation of periods (TRUE/FALSE)

ignoreData: Object of class "vector" Booleans

<code>ignoreE</code>	Ignore the specified exposure (E) event times
<code>ignoreI</code>	Ignore the specified infective (I) event times
<code>ignoreD</code>	Ignore the specified diagnose (D) event time

initBeta: Object of class "list" Initial values:

<code>init</code>	for β
<code>gamma</code>	for the priori parameter γ
<code>delta</code>	for the priori parameter δ

initBetaN: Object of class "list" Initial values:

<code>init</code>	for β_n
<code>gamma</code>	for the priori parameter γ
<code>delta</code>	for the priori parameter δ

initIncu: Object of class "list" Initial values:

<code>g</code>	for parameter γ of the gamma distribution of the incubation time
----------------	---

g.gamma	for the parameter <i>gamma</i> of the distribution of g
g.delta	for the parameter <i>delta</i> of the distribution of g
d	for parameter δ of the gamma distribution of the incubation time
d.gamma	for the parameter <i>gamma</i> of the distribution of d
d.delta	for the parameter <i>delta</i> of the distribution of d

or choose asis or constant:

asis	TRUE/FALSE
const	TRUE/FALSE
const.val	value of constant if const == TRUE

initInf: Object of class "list" Initial values:

g	for parameter γ of the gamma distribution of the infectious time
g.gamma	for the parameter <i>gamma</i> of the distribution of g
g.delta	for the parameter <i>delta</i> of the distribution of g
d	for parameter δ of the gamma distribution of the infectious time
d.gamma	for the parameter <i>gamma</i> of the distribution of d
d.delta	for the parameter <i>delta</i> of the distribution of d

initDia: Object of class "list" Initial values:

g	for parameter γ of the gamma distribution of the seroconversion time
g.gamma	for the parameter <i>gamma</i> of the distribution of g
g.delta	for the parameter <i>delta</i> of the distribution of g
d	for parameter δ of the gamma distribution of the seroconversion time
d.gamma	for the parameter <i>gamma</i> of the distribution of d
d.delta	for the parameter <i>delta</i> of the distribution of d

Methods

ignoreData signature(object = "LBOptions"):
returns value of slot ignoreData

ignoreData<- signature(object = "LBOptions", value = "vector"):
assigns value to slot ignoreData

initBeta signature(object = "LBOptions"):
returns value of slot initBeta

initBeta<- signature(object = "LBOptions", value = "list"):
assigns value to slot initBeta

initBetaN signature(object = "LBOptions"):
returns value of slot initBetaN

initBetaN<- signature(object = "LBOptions", value = "list"):
assigns value to slot initBetaN

initDia signature(object = "LBOptions"):
returns value of slot initDia

initDia<- signature(object = "LBOptions", value = "list"):
assigns value to slot initDia

initialize signature(.Object = "LBOptions"):
does initializing of the slots when new("LBOptions", ...) is called

initIncu signature(object = "LBOptions"):
returns value of slot initIncu

initIncu<- signature(object = "LBOptions", value = "list"):
assigns value to slot initIncu

initInf signature(object = "LBOptions"):
returns value of slot initInf

initInf<- signature(object = "LBOptions", value = "list"):
assigns value to slot initInf

initsAsDataFrame signature(object = "LBOptions"):
returns initial values in a dataframe format

LBInits signature(object = "LBOptions"):
returns all initial values (as there are initBeta, initBetaN, initIncu, initInf, initDia)

LBInits<- signature(object = "LBOptions", value = "list"):
assigns value to all initial value slots (as there are initBeta, initBetaN, initIncu, initInf, initDia)

LBModel signature(object = "LBOptions"):
returns value of slot LBModel

LBModel<- signature(object = "LBOptions", value = "vector"):
assigns value to slot LBModel

LBOptions signature(object = "LBOptions"):
returns values of real option slots (as there are seed, LBModel, ignoreData)

LBOptions<- signature(object = "LBOptions", value = "list"):
assigns value to real option slots (as there are seed, LBModel, ignoreData)

optionsAsDataFrame signature(object = "LBOptions"):
returns real option values in a dataframe format

seed signature(object = "LBOptions"):
returns value of slot seed

seed<- signature(object = "LBOptions", value = "numeric"):
assigns value to slot seed

show signature(object = "LBOptions"):
shows the object

simulate signature(object = "LBOptions", layout = "Layout"):
simulates data according to the specified model and init values and the given layout structure

summary signature(object = "LBOptions"):
gives a summary of the object (at the moment no difference to show)

Author(s)

M. Hoehle and U. Feldmann

See Also

See also [LBOptionsMCMC-class](#) and [LBOptionsML-class](#)

Examples

```

opts <- new( "LBOptions", seed=2003,
            LBmodel=c( "gamma", "gamma", "gamma", FALSE ),
            ignoreData=c( TRUE, FALSE, FALSE ),
            initBeta=list( 0.125, 0.001, 0.001 ),
            initBetaN=list( init=0.018, gamma=0.001, delta=0.001 ),
            initIncu=list( g=6.697, g.gamma=0.001, g.delta=0.001,
                          d=0.840, d.gamma=0.001, d.delta=0.001 ),
            initInf=list( 1.772, 0.001, 0.001, 0.123, 0.001, 0.001 ),
            initDia=list( 149.126, 0.001, 0.001, 8.737, 0.001, 0.001 ) )
layout <- new( "LBLayout", S0=matrix( c( 14, 14 ), ncol=2 ),
              E0=matrix( c( 0, 1 ), ncol=2 ) )

exp <- simulate( opts, layout=layout )

```

LBOptionsMCMC-class *Class "LBOptionsMCMC" – Specification of MCMC estimation in SEIR models.*

Description

Specification of MCMC estimation in SEIR models.

Objects from the Class

Objects can be created by calls of the form `new("LBOptionsMCMC", seed, LBmodel, ignoreData, initBeta, initBetaN, initIncu, initInf, initDia, algo, randomWalk)`.

Slots

algo: Object of class "vector". Contains a specification of the MCMC algorithm, i.e. a vector with names

samples	how many? (without burnin)
thin	how to thin the random numbers
burnin	the first x random numbers will be ignored

randomWalk: Object of class "vector". Contains a specification of the random walk, i.e. a vector with names

betaRwsigma sigma concerning parameter β

betaNRWsigma	sigma concerning parameter β_n
gammaERWsigma	sigma concerning parameter γ of the gamma distribution of the incubation time
deltaERWsigma	sigma concerning parameter δ of the gamma distribution of the incubation time
gammaIRWsigma	sigma concerning parameter γ of the gamma distribution of the infectious time
deltaIRWsigma	sigma concerning parameter δ of the gamma distribution of the infectious time
gammaDRWsigma	sigma concerning parameter γ of the gamma distribution of the seroconversion time
deltaDRWsigma	sigma concerning parameter δ of the gamma distribution of the seroconversion time
ERWsigma	sigma concerning unknown exposure times

seed: Object of class "numeric". The seed value to use when calling the Java program

LBmodel: Object of class "vector". Contains a specification of the SEIR model, i.e. a vector with names

incuTimePDF	distribution of incubation time
infTimePDF	distribution of the infectious time
diagTimePDF	distribution of the seroconversion time
meanVar	mean variance representation of periods (TRUE/FALSE)

ignoreData: Object of class "vector". Booleans

ignoreE	Ignore the specified exposure (E) event times
ignoreI	Ignore the specified infective (I) event times
ignoreD	Ignore the specified diagnose (D) event time

initBeta: Object of class "list". Initial values:

init	for β
gamma	for the priori parameter γ
delta	for the priori parameter δ

initBetaN: Object of class "list". Initial values:

init	for β_n
gamma	for the priori parameter γ
delta	for the priori parameter δ

initIncu: Object of class "list". Initial values:

g	for parameter γ of the gamma distribution of the incubation time
g.gamma	for the parameter <i>gamma</i> of the distribution of g
g.delta	for the parameter <i>delta</i> of the distribution of g
d	for parameter δ of the gamma distribution of the incubation time
d.gamma	for the parameter <i>gamma</i> of the distribution of d
d.delta	for the parameter <i>delta</i> of the distribution of d

or choose asis or constant:

asis	TRUE/FALSE
const	TRUE/FALSE
const.val	value of constant if const == TRUE

initInf: Object of class "list". Initial values:

g	for parameter γ of the gamma distribution of the infectious time
g.gamma	for the parameter <i>gamma</i> of the distribution of g
g.delta	for the parameter <i>delta</i> of the distribution of g
d	for parameter δ of the gamma distribution of the infectious time
d.gamma	for the parameter <i>gamma</i> of the distribution of d
d.delta	for the parameter <i>delta</i> of the distribution of d

initDia: Object of class "list". Initial values:

g	for parameter γ of the gamma distribution of the seroconversion time
g.gamma	for the parameter <i>gamma</i> of the distribution of g
g.delta	for the parameter <i>delta</i> of the distribution of g
d	for parameter δ of the gamma distribution of the seroconversion time
d.gamma	for the parameter <i>gamma</i> of the distribution of d
d.delta	for the parameter <i>delta</i> of the distribution of d

Extends

Class "LBOptions", directly.

Methods

algo signature(object = "LBOptionsMCMC"):
returns value of slot algo

algo<- signature(object = "LBOptionsMCMC", value = "vector"):
assigns value to slot algo

LBOptions signature(object = "LBOptionsMCMC"):
returns values of real option slots (as there are seed, LBModel, ignoreData, algo, randomWalk
)

LBOptions<- signature(object = "LBOptionsMCMC", value = "list"):
assigns value to real option slots (as there are seed, LBModel, ignoreData, algo, randomWalk
)

optionsAsDataFrame signature(object = "LBOptionsMCMC"):
returns real option values in a dataframe format

randomWalk signature(object = "LBOptionsMCMC"):
returns value of slot randomWalk

randomWalk<- signature(object = "LBOptionsMCMC", value = "vector"):
 assigns value to slot randomWalk

show signature(object = "LBOptionsMCMC"):
 shows the object

summary signature(object = "LBOptionsMCMC"):
 gives a summary of the object (at the moment no difference to show)

writeOptionFile signature(object = "LBOptionsMCMC", filename="vector"):
 writes a file containing all options as input for java

Author(s)

M. Hoehle and U. Feldmann

See Also

See also [LBOptions-class](#) and [LBOptionsML-class](#)

Examples

```
opts <- new( "LBOptionsMCMC", algo=c( samples=2500, thin=25, burnin=50000 ),
           randomWalk=c( "betaRwsigma"= 0.1,
                        "betaNRwsigma"=0.1,
                        "gammaERwsigma"=3,
                        "deltaERwsigma"=1,
                        "gammaIRwsigma"=1,
                        "deltaIRwsigma"=1,
                        "gammaDRwsigma"=3,
                        "deltaDRwsigma"=1,
                        "ERwsigma"=6 ),
           seed=2003,
           LBmodel=c( "gamma", "gamma", "gamma", FALSE ),
           ignoreData=c( TRUE, FALSE, TRUE ),
           initBeta=list( 0.4, 0.001, 0.001 ),
           initBetaN=list( init=0.005, gamma=0.001, delta=0.001 ),
           initIncu=list( g=1, g.gamma=0.001, g.delta=0.001,
                        d=0.11, d.gamma=0.001, d.delta=0.001 ),
           initInf=list( 1, 0.001, 0.001, 0.11, 0.001, 0.001 ),
           initDia=list( 8, 0.001, 0.001, 0.8, 0.001, 0.001 ) )
```

LBOptionsML-class	<i>Class "LBOptionsML" – maximum likelihood inference in SEIR models</i>
-------------------	--

Description

Specification of LadyBug SEIR models using maximum likelihood inference

Objects from the Class

Objects can be created by calls of the form `new("LBOptionsML", seed, LBmodel, ignoreData, initBeta, initBetaN, initIncu, initInf, initDia, algo, randomWalk)`.

Slots

seed: Object of class "numeric" The seed value to use when calling the Java program

LBmodel: Object of class "vector" Contains a specification of the SEIR model, i.e. a vector with names

<code>incuTimePDF</code>	distribution of incubation time
<code>infTimePDF</code>	distribution of the infectious time
<code>diagTimePDF</code>	distribution of the seroconversion time
<code>meanVar</code>	mean variance representation of periods (TRUE/FALSE)

ignoreData: Object of class "vector" Booleans

<code>ignoreE</code>	Ignore the specified exposure (E) event times
<code>ignoreI</code>	Ignore the specified infective (I) event times
<code>ignoreD</code>	Ignore the specified diagnose (D) event time

initBeta: Object of class "list" Initial values:

<code>init</code>	for β
<code>gamma</code>	for the priori parameter γ
<code>delta</code>	for the priori parameter δ

initBetaN: Object of class "list" Initial values:

<code>init</code>	for β_n
<code>gamma</code>	for the priori parameter γ
<code>delta</code>	for the priori parameter δ

initIncu: Object of class "list" Initial values:

<code>g</code>	for parameter γ of the gamma distribution of the incubation time
<code>g.gamma</code>	for the parameter <i>gamma</i> of the distribution of g
<code>g.delta</code>	for the parameter <i>delta</i> of the distribution of g
<code>d</code>	for parameter δ of the gamma distribution of the incubation time
<code>d.gamma</code>	for the parameter <i>gamma</i> of the distribution of d
<code>d.delta</code>	for the parameter <i>delta</i> of the distribution of d

or choose asis or constant:

<code>asis</code>	TRUE/FALSE
-------------------	------------

```

const      TRUE/FALSE
const.val  value of constant if const == TRUE

```

initInf: Object of class "list" Initial values:

```

g          for parameter  $\gamma$  of the gamma distribution of the infectious time
g.gamma   for the parameter gamma of the distribution of g
g.delta   for the parameter delta of the distribution of g
d          for parameter  $\delta$  of the gamma distribution of the infectious time
d.gamma   for the parameter gamma of the distribution of d
d.delta   for the parameter delta of the distribution of d

```

initDia: Object of class "list" Initial values:

```

g          for parameter  $\gamma$  of the gamma distribution of the seroconversion time
g.gamma   for the parameter gamma of the distribution of g
g.delta   for the parameter delta of the distribution of g
d          for parameter  $\delta$  of the gamma distribution of the seroconversion time
d.gamma   for the parameter gamma of the distribution of d
d.delta   for the parameter delta of the distribution of d

```

Extends

Class "LBOptions", directly.

Methods

show signature(object = "LBOptionsML"):
shows the object

summary signature(object = "LBOptionsML"):
gives a summary of the object (at the moment no difference to show)

writeOptionFile signature(object = "LBOptionsML", filename = "vector"):
writes a file containing all options as input for java

Author(s)

M. Hoehle and U. Feldmann

See Also

See also [LBOptions-class](#) and [LBOptionsMCMC-class](#)

Examples

```

opts <- new( "LBOptionsML", seed=2003,
            LBmodel=c( "constant", "gamma", "none", FALSE ),
            ignoreData=c( FALSE, FALSE, FALSE ),

```

```

initBeta=list( 0.4, 0.001, 0.001 ),
initBetaN=list( init=0.005, gamma=0.001, delta=0.001 ),
initIncu=list( asis=TRUE ),
initInf=list( 1, 0.001, 0.001, 0.11, 0.001, 0.001 ),
initDia=list( 8, 0.001, 0.001, 0.8, 0.001, 0.001 ) )

```

oneill

Simulated data of 5 recovery times from O'Neill et. al

Description

Use MCMC to estimate parameters in the 5 point epidemic in the 5 removal times epidemic (p.126) of the article by O'Neill and Roberts.

Usage

```
data(oneill)
```

Details

n.a.

Source

O'Neill, P. D. and Roberts, G. O. (1999). Bayesian inference for partially observed stochastic epidemics. J. R. Statist. Soc. A 162, 121–129.

Examples

```

## Not run: data(oneill)
## Not run: seir(oneill,oneill.opts)

```

readSpecFile

Read LadyBug files and create corresponding S4 RLadyBug objects

Description

Data and specification files in the LadyBug files are read and converted to S4 RLadyBug objects.

Usage

```
readSpecFile(options, data)
```

Arguments

options	Filename of the LadyBug options (i.e. the .sir) file
data	Filename of the Data in LadyBug format

Details

n.a.

Value

A list containing

options The information relevant to the Options

experiment An object of class Object containing the layout and the event times of the data

Author(s)

U. Feldmann and M. Höhle

Examples

```
## Not run: csfv <- readSpecFile( ladybugExample( "/csfv/mcmc.sir"),ladybugExample( "/csfv/csfv.data" ))
## Show the MCMC options
## Not run: csfv$options
## Show the layout and initial configuration
## Not run: csfv$experiment
```

seir

Parameter estimation in SEIR-Models based on ML or MCMC

Description

Inference is performed for the parameters in an SEIR-model based on the data in experiment. The actual class of options (OptionsML or OptionsMCMC) decides what type of inference is performed.

Usage

```
seir(experiment, options, debug = FALSE)
```

Arguments

experiment Data corresponding to an Experiment

options An object of class Options. The specific action (ML or MCMC estimation) is determined by the subclass of options.

debug Boolean (default FALSE) specifying whether to yield additional debug information in case of problems. For example the ladybug.system.out and ladybug.system.err are not removed after the call and can be found in the current working directory.

Details

Estimation is performed by calling LadyBug using a `.jcall` to the appropriate method in the Java class `sir.estimate.LadyBug`. Output is read from file and converted into an appropriate object of class [LBInference-class](#).

Currently the method branches on the appropriate method using an `if`. Should become a generic method as some point.

Note that the `system.out` and `system.err` from the java call are saved in the current working directory (the directory has to be writable). After a successful call the files are deleted unless one uses the debug option.

Value

An object of class `Inference`

Author(s)

U. Feldmann and M. Höhle

See Also

[LBOptions-class](#), [LBOptionsML-class](#), [LBOptionsMCMC-class](#)

Examples

```
data(csfvML)
ml <- seir(csfvML, csfvML.opts)
ml

#MCMC Inference for the data from the Laevens experiment
data(laevens)
inf.mcmc <- seir(laevens, laevens.opts)
#Show some results
inf.mcmc

#Analysis through coda (library coda is called when starting RLadyBug)
samples <- mcmc(samplePaths(inf.mcmc))
plot(samples[, "beta"])
```

twinSIR

Spatio-Temporal Epidemic Modelling Using Additive-Multiplicative Intensity Models

Description

twinSIR is used to fit additive-multiplicative intensity models for epidemics as described in Höhle (2008). Estimation is driven by (penalized) maximum likelihood in the point process frame work. Optimization (maximization) of the (penalized) likelihood function is performed by means of [optim](#).

Usage

```
twinSIR(formula, data, weights, subset,
        knots = NULL, nIntervals = 1, lambda.smooth = 0, penalty = 1,
        optim.args = list(), model = TRUE, keep.data = FALSE)
```

Arguments

- | | |
|---------------|---|
| formula | an object of class " formula " (or one that can be coerced to that class): a symbolic description of the intensity model to be estimated. The details of model specification are given under Details. |
| data | an object inheriting from class " epidata ". |
| weights | an optional vector of weights to be used in the fitting process. Should be NULL (the default, i.e. all observations have unit weight) or a numeric vector. |
| subset | an optional vector specifying a subset of observations to be used in the fitting process. The subset <code>atRiskY == 1</code> is automatically chosen, because the likelihood only depends on those observations. |
| knots | numeric vector or NULL (the default). Specification of the knots, where we suppose a step of the log-baseline. With the current implementation, these must be existing "stop" time points in <code>subset(data, atRiskY == 1)</code> . The intervals of constant log-baseline hazard rate then are $(minTime; knots_1]$, $(knots_1; knots_2]$, ..., $(knots_K; maxTime]$. By default, the knots are automatically chosen at the quantiles of the infection time points such that <code>nIntervals</code> intervals result. Non-NULL knots take precedence over <code>nIntervals</code> . |
| nIntervals | the number of intervals of constant log-baseline hazard. Defaults to 1, which means an overall constant log-baseline hazard will be fitted. |
| lambda.smooth | numeric, the smoothing parameter λ . By default it is 0 which leads to unpenalized likelihood inference. In case the value is specified as "-1" then the automatic smoothing parameter selection based on a mixed model approach is used. |
| penalty | either a single number denoting the order of the difference used to penalize the log-baseline coefficients (defaults to 1), or a more specific penalty matrix K for the parameter sub-vector β . In case of non-equidistant knots – usually the case when using quantile based knot locations – a 1st order differences penalty matrix as in Fahrmeir and Lang (2001) is available. For non-equidistant knots higher orders than one are not implemented. |
| optim.args | a list with arguments passed to the <code>optim</code> function. Especially useful are the following ones:
par: to specify initial parameter values. Those must be in the order <code>c(alpha, h0, beta)</code> , i.e. first the coefficients of the epidemic covariates in the same order as they appear in the <code>formula</code> , then the log-baseline levels in chronological order and finally the coefficients of the endemic covariates in the same order as they appear in the cox terms of the <code>formula</code> . The default is to start with 1's for <code>alpha</code> and 0's for <code>h0</code> and <code>beta</code> .
control: for more detailed trace-ing (default: 1), another <code>REPORT</code> -ing frequency if trace is positive (default: 10), higher <code>maxit</code> (maximum number of iterations, default: 300) or another <code>factr</code> value (default: <code>1e7</code> , a lower value means higher precision). |

	<p>method: the optimization algorithm defaults to "L-BFGS-B" (for box-constrained optimization), if there are any epidemic (non-cox) variables in the model, and to "BFGS" otherwise.</p> <p>lower: if <code>method = "L-BFGS-B"</code> this defines the lower bounds for the model coefficients. By default, all effects α of epidemic variables are restricted to be non-negative. Normally, this is exactly what one would like to have, but there might be reasons for other lower bounds, see the Note below.</p> <p>hessian: An estimation of the Expected Fisher Information matrix is always part of the return value of the function. It might be interesting to see the Observed Fisher Information (= negative Hessian at the maximum), too. This will be additionally returned if <code>hessian = TRUE</code>.</p>
<code>model</code>	logical indicating if the model frame, the weights, <code>lambda.smooth</code> , the penalty matrix K and the list of used distance functions f (from <code>attributes(data)</code>) should be returned for further computation. This defaults to <code>TRUE</code> as this information is necessary e.g. in the <code>profile</code> and <code>plot</code> methods.
<code>keep.data</code>	logical indicating if the "epidata" object 'data' should be part of the return value. This is only necessary for the use of the <code>simulate</code> method for "twinSIR" objects. The reason is that the <code>twinSIR</code> function only uses and stores the rows with <code>atRiskY == 1</code> in the <code>model</code> component, but for the simulation of new epidemic data one needs the whole data set with all individuals in every time block. The default value is <code>FALSE</code> , so if you intent to use <code>simulate.twinSIR</code> , you have to set this to <code>TRUE</code> .

Details

A model is specified through the formula, which has the form $\sim \text{epidemicTerm1} + \text{epidemicTerm2} + \text{cox}(\text{endemicVar1}) * \text{cox}(\text{endemicVar2})$, i.e. the right hand side has the usual form as in `lm` with some variables marked as being endemic by the special function `cox`. The left hand side of the formula is empty and will be set internally to `cbind(start, stop, event)`, which is similar to `Surv(start, stop, event, type="counting")`.

Basically, the additive-multiplicative model for the infection intensity $\lambda_i(t)$ for individual i is

$$\lambda_i(t) = Y_i(t) * (e_i(t) + h_i(t))$$

where

$Y_i(t)$ is the at-risk indicator, indicating if individual i is "at risk" of becoming infected at time point t . This variable is part of the event history data.

$e_i(t)$ is the epidemic component of the infection intensity, defined as

$$e_i(t) = \sum_{j \in I(t)} f(\|s_i - s_j\|)$$

where $I(t)$ is the set of infectious individuals just before time point t , s_i is the coordinate vector of individual i and the function f is defined as

$$f(u) = \sum_{m=1}^p \alpha_m B_m(u)$$

with unknown transmission parameters α and known distance functions B_m . This set of distance functions results in the set of epidemic variables normally calculated by the converter function `as.epidata`, considering the equality

$$e_i(t) = \sum_{m=1}^p \alpha_m x_{im}(t)$$

with $x_{im}(t) = \sum_{j \in I(t)} B_m(\|s_i - s_j\|)$ being the m 'th epidemic variable for individual i .

$h_i(t)$ is the endemic (cox) component of the infection intensity, defined as

$$h_i(t) = \exp(h_0(t) + z_i(t)' \beta)$$

where $h_0(t)$ is the log-baseline hazard function, $z_i(t)$ is the vector of endemic covariates of individual i and β is the vector of unknown coefficients. To fit the model, the log-baseline hazard function is approximated by a piecewise constant function with known knots, but unknown levels, which will be estimated. The approximation is specified by the arguments `knots` or `nIntervals`.

If a big number of knots (or `nIntervals`) is chosen, the corresponding log-baseline parameters can be rendered identifiable by the use of penalized likelihood inference. At present, it is the job of the user to choose an adequate value of the smoothing parameter `lambda.smooth`. Alternatively, a data driven `lambda.smooth` smoothing parameter selection based on a mixed model representation of an equivalent truncated power spline is offered (see reference for further details). The following two steps are iterated until convergence:

1. Given fixed smoothing parameter, the penalized likelihood is optimized for the regression components using a L-BFGS-B approach
2. Given fixed regression parameters, a Laplace approximation of the marginal likelihood for the smoothing parameter is numerically optimized.

Depending on the data convergence might take a couple of iterations.

Note also that it is unwise to include endemic covariates with huge values, as they affect the intensities on the exponential scale after having been multiplied by the parameter vector β . With big covariates the `optim` method "L-BFGS-B" will likely terminate due to an infinite log-likelihood or score function in some iteration.

Value

`twinSIR` returns an object of `class "twinSIR"`. An object of this class is a list containing the following components:

<code>coefficients</code>	a named vector of coefficients.
<code>loglik</code>	the maximum of the (penalized) log-likelihood function.
<code>counts</code>	the number of log-likelihood and score function evaluations.
<code>converged</code>	logical indicating convergence of the optimization algorithm.
<code>fisherinfo.observed</code>	if requested, the negative Hessian from <code>optim</code> .
<code>fisherinfo</code>	an estimation of the Expected Fisher Information matrix.

method	the optimization algorithm used.
intervals	a numeric vector (<code>c(minTime, knots, maxTime)</code>) representing the consecutive intervals of constant log-baseline.
nEvents	a numeric vector containing the number of infections in each of the above intervals.
model	if requested, the model information used. This is a list with components "survs" (data.frame with the id, start, stop and event columns), "X" (matrix of the epidemic variables), "Z" (matrix of the endemic variables), "weights" (the specified weights), "lambda.smooth" (the specified lambda.smooth), "K" (the penalty matrix used) and "f" (the distance functions used). Be aware that the model only contains those rows with <code>atRiskY == 1!</code>
data	if requested, the supplied "epidata" data.
call	the matched call.
formula	the specified formula.
terms	the terms object used.

Note

There are some restrictions to modelling the infection intensity without a baseline hazard rate, i.e. without an intercept in the formula. Reason: At some point, the optimization algorithm L-BFGS-B tries to set all transmission parameters α to the boundary value 0 and to calculate the (penalized) score function with this set of parameters (all 0). The problem then is that the values of the infection intensities $\lambda_{i}(t)$ are 0 for all i and t and especially at observed event times, which is impossible. Without a baseline, it is not allowed to have all alpha's set to 0, because then we would not observe any infections. Unfortunately, L-BFGS-B can not consider this restriction. Thus, if one wants to fit a model without baseline hazard, the control parameter lower must be specified in `optim.args` so that some alpha is strictly positive, e.g. `optim.args = list(lower = c(0, 0.001, 0.001, 0))` and the initial parameter vector `par` must not be the zero vector.

Author(s)

Michael Höhle and Sebastian Meyer

References

- Höhle, M. (2009), Additive-Multiplicative Regression Models for Spatio-Temporal Epidemics, Accepted for publication in the Biometrical Journal.
- Höhle, M. (2008) Spatio-temporal epidemic modelling using additive-multiplicative intensity models. *Ludwig-Maximilians-Universität, Department of Statistics: Technical Reports*, No. 41. Available at <http://epub.ub.uni-muenchen.de/6366/>.

See Also

[as.epidata](#) for the necessary data input structure, [plot.twinSIR](#) for plotting the path of the infection intensity, [profile.twinSIR](#) for profile likelihood estimation. and [simulate.twinSIR](#) for the simulation of epidemics following the fitted model.

Furthermore, the standard extraction methods `coef`, `vcov`, `logLik`, `AIC` and `extractAIC` are implemented for objects of class "twinSIR".

Examples

```

data("fooePIData")
summary(fooePIData)

# fit an overall constant baseline hazard rate
fit1 <- twinSIR(~ B1 + B2 + cox(z2), data = fooePIData, keep.data = TRUE)
fit1
summary(fit1)

# fit a piecewise constant baseline hazard rate with 3 intervals using
# _un_penalized ML and estimated coefs from fit1 as starting values
fit2 <- twinSIR(~ B1 + B2 + cox(z2), data = fooePIData, nIntervals = 3,
  optim.args = list(par=c(coef(fit1)[1:2],rep(coef(fit1)[3],3),coef(fit1)[4])))
fit2
summary(fit2)

# fit a piecewise constant baseline hazard rate with 9 intervals
# using _penalized ML and estimated coefs from fit1 as starting values
fit3 <- twinSIR(~ B1 + B2 + cox(z2), data = fooePIData, nIntervals = 9,
  lambda.smooth = 0.1, penalty = 1, optim.args = list(
  par=c(coef(fit1)[1:2], rep(coef(fit1)[3],9), coef(fit1)[4])))
fit3
summary(fit3)
# plot of the 9 log-baseline levels
plot(x=fit3$intervals, y=coef(fit3)[c(3,3:11)], type="S")

### -> for more sophisticated intensity plots, see 'plot.twinSIR'
plot(fit3)

```

twinSIR_epidata *Class for Epidemic Data*

Description

The function `as.epidata` converts a matrix or a data frame into an object of `class "epidata"`. Objects of this class are specific data frames containing the event history of an epidemic together with some additional attributes. These objects are the basis for fitting spatio-temporal epidemic intensity models with the function `twinSIR`. Note that the spatial information itself, i.e. the positions of the individuals, is assumed to be constant over time. Besides epidemics following the SIR compartmental model, also data from SI, SIRS and SIS epidemics may be supplied. Inference for the infectious process works as usual and simulation of such epidemics is also possible.

Usage

```

as.epidata(data, id.col, start.col, stop.col, atRiskY.col,
  event.col, Revent.col, coords.cols, f = list())

## S3 method for class 'epidata'
print(x, ...)

```

```
## S3 method for class 'epidata'
x[i, j, drop]
```

Arguments

data	<p>a matrix or a data.frame. It contains the observed event history in a form similar to <code>Surv(, type="counting")</code> with additional information (variables) along the process. It must not be sorted in any specific order; this will be done automatically during conversion. The observation period is splitted up into <i>consecutive</i> intervals of constant state - thus constant infection intensities. The data frame consists of a block of N (number of individuals) rows for each of those time intervals (all rows in a block share the same start and stop values... therefore the name "block"), where there is one row per individual in the block. Each row describes the (fixed) state of the individual during the interval given by the start and stop columns <code>start.col</code> and <code>stop.col</code>.</p> <p>Note that there may not be more than one event (infection or removal) in a single block. Thus, in a single block, only one entry in the <code>event.col</code> and <code>Revent.col</code> may be 1, all others are 0. This rule follows the assumption that there are no concurrent events (infections or removals).</p>
id.col	<p>single index of the <code>id</code> column in data. Can be numeric (by column number) or character (by column name). The <code>id</code> column identifies the individuals in the data frame. It will be converted to a factor variable.</p>
start.col	<p>single index of the <code>start</code> column in data. Can be numeric (by column number) or character (by column name). The <code>start</code> column contains the (numeric) time points of the beginnings of the consecutive time intervals of the event history. The minimum value in this column, i.e. the start of the observation period should be 0.</p>
stop.col	<p>single index of the <code>stop</code> column in data. Can be numeric (by column number) or character (by column name). The <code>stop</code> column contains the (numeric) time points of the ends of the consecutive time intervals of the event history. The stop value must always be greater than the start value of a row.</p>
atRiskY.col	<p>single index of the <code>atRiskY</code> column in data. Can be numeric (by column number) or character (by column name). The <code>atRiskY</code> column indicates if the individual was "at-risk" of becoming infected during the time interval (<code>start</code>; <code>stop</code>]. This variable must be logical or in 0/1-coding. Individuals with <code>atRiskY == 0</code> in the first time interval (normally the rows with <code>start == 0</code>) are taken as <i>initially infectious</i>.</p>
event.col	<p>single index of the <code>event</code> column in data. Can be numeric (by column number) or character (by column name). The <code>event</code> column indicates if the individual became <i>infected</i> at the stop time of the interval. This variable must be logical or in 0/1-coding.</p>
Revent.col	<p>single index of the <code>Revent</code> column in data. Can be numeric (by column number) or character (by column name). The <code>Revent</code> column indicates if the individual was <i>recovered</i> at the stop time of the interval. This variable must be logical or in 0/1-coding.</p>
coords.cols	<p>indexes of the <code>coords</code> columns in data. Can be a numeric (by column number) vector, a character (by column name) vector or NULL (in which case epidemic</p>

covariates are not calculatable). These columns contain the coordinates of the individuals. It must be emphasized that the functions in this package currently assume *fixed positions* of the individuals during the whole epidemic. Thus, an individual has the same coordinates in every block. For simplicity, the coordinates are derived from the first time block only (normally the rows with `start == 0`). The epidemic covariates are calculated based on the euclidian distances between the individuals, see `f`.

`f` a *named* list of distance functions or `list()` (the default), if calculation of epidemic covariates is not requested. The functions must interact elementwise on a (distance) matrix so that - for a matrix `D` - `f[[m]](D)` results in a matrix. A simple example is `function(u) {u <= 1}`, which indicates if the euclidian distance between the individuals is smaller than or equal to 1. To ensure that an individual does not influence itself, the distance to itself is defined as `Inf`. Consequently, all of the distance functions must have the property `f[[m]](Inf) = 0`. The names of the functions will be the names of the epidemic variables in the resulting data frame. The value of such a variable is computed as follows: $I(t)$ denotes the set of infectious individuals just before time t and s_i the coordinate vector of individual i . For individual i at time t the epidemic component m has the value $\sum_{j \in I(t)} f_m(\|s_i - s_j\|)$

`x` an object of class "epidata".

`...` arguments passed to `print.data.frame`.

`i, j, drop` arguments passed to `[.data.frame`.

Details

The `print` method for objects of class "epidata" simply prints the data frame with a small header containing the time range of the observed epidemic and the number of infected individuals. Usually, the data frames are quite long, so the summary method `summary.epidata` might be useful. Also, indexing/subsetting "epidata" works exactly as for `data.frames`, but there is an own method, which assures consistency of the resulting "epidata" or drops this class, if necessary.

SIS epidemics are implemented as SIRS epidemics where the length of the removal period equals 0. This means that an individual, which has an R-event will be at risk immediately afterwards, i.e. in the following time block. Therefore, data of SIS epidemics have to be provided in that form containing "pseudo-R-events".

Value

a data.frame with the columns "BLOCK", "id", "start", "stop", "atRiskY", "event", "Revent" and the coordinate columns (with the original names from data), which are all obligatory. These columns are followed by any remaining columns of the input data. Last but not least, the newly generated columns with epidemic variables corresponding to the functions in the list `f` are appended, if `length(f) > 0`.

The data.frame is given the additional *attributes*

"eventTimes" numeric vector of infection time points (sorted chronologically).
 "timeRange" numeric vector of length 2: `c(min(start), max(stop))`.

"coords.cols" numeric vector containing the column indices of the coordinate columns in the resulting data frame.

"f" this equals the argument f.

Note

The column name "BLOCK" is a reserved name. This column will be added automatically at conversion and the resulting data frame will be sorted by this column and by id. Also the names "id", "start", "stop", "atRiskY", "event" and "Revent" are reserved for the respective columns only.

Author(s)

Sebastian Meyer

See Also

The [plot](#) and the [summary](#) method for class "epidata". Furthermore, the function [animate.epidata](#) for the animation of epidemics.

Function [twinSIR](#) for fitting spatio-temporal epidemic intensity models to epidemic data.

Function [simEpidata](#) for the simulation of epidemic data.

Examples

```
# an artificial example of an event history from the package
data("foodata")
str(foodata)

# convert the data to an object of class "epidata",
# also generating some epidemic covariates
myEpidata <- as.epidata(foodata, id.col = 1, start.col = "start",
  stop.col = "stop", atRiskY.col = "atrisk", event.col = "infected",
  Revent.col = "removed", coords.cols = c("x", "y"),
  f = list(B1 = function(u) u<=1,
    B2 = function(u) u>1 & is.finite(u))
)
# note the is.finite restriction in B2 to ensure that f[[i]](Inf) = 0, for all i

str(myEpidata)
subset(myEpidata, BLOCK == 1)

summary(myEpidata)      # see 'summary.epidata'
plot(myEpidata)         # see 'plot.epidata' and also 'animate.epidata'
stateplot(myEpidata, "15") # see 'stateplot'

## Not run: # works in interactive mode, but not in R CMD check
data("foepidata")
stopifnot(identical(myEpidata, foepidata))

## End(Not run)
```

 twinSIR_epidata_animate

Spatio-Temporal Animation of an Epidemic

Description

Function for the animation of epidemic data, i.e. objects inheriting from class "epidata". This only works with 1- or 2-dimensional coordinates and is not useful if some individuals share the same coordinates (overlapping). There are two types of animation, see argument `time.spacing`. Besides the direct plotting in the R session, it is also possible to generate a sequence of graphics files to create animations outside R.

Usage

```
## S3 method for class 'summary.epidata'
animate(object, main = "An animation of the epidemic",
        pch = 19, col = c(3, 2, gray(0.6)), time.spacing = NULL,
        sleep = quote(5/.nTimes), legend.opts = list(), timer.opts = list(),
        end = NULL, generate.snapshots = NULL, ...)

## S3 method for class 'epidata'
animate(object, ...)
```

Arguments

<code>object</code>	an object inheriting from class "epidata" or "summary.epidata". In the former case, its summary is calculated and the function continues as in the latter case, passing all ... arguments to the <code>summary.epidata</code> method.
<code>main</code>	a main title for the plot, see also title .
<code>pch, col</code>	vectors of length 3 specifying the point symbols and colors for susceptible, infectious and removed individuals (in this order). The vectors are recycled if necessary. By default, susceptible individuals are marked as filled green circles, infectious individuals as filled red circles and removed individuals as filled gray circles. Note that the symbols are iteratively drawn (overlaid) in the same plotting region as time proceeds. For information about the possible values of <code>pch</code> and <code>col</code> , see the help pages of points and par , respectively.
<code>time.spacing</code>	time interval for the animation steps. If NULL (the default), the events are plotted one by one with pauses of <code>sleep</code> seconds. Thus, it is just the <i>ordering</i> of the events, which is shown. To plot the appearance of events proportionally to the exact time line, <code>time.spacing</code> can be set to a numeric value indicating the period of time between consecutive plots. Then, for each time point in <code>seq(0, end, by = time.spacing)</code> the current state of the epidemic can be seen and an additional timer indicates the current time (see <code>timer.opts</code> below). The argument <code>sleep</code> will be the artificial pause in seconds between two of those time points.

sleep	time in seconds to <code>Sys.sleep</code> before the next plotting event. By default, each artificial pause is of length $5/.nTimes$ seconds, where <code>.nTimes</code> is the number of events (infections and removals) of the epidemic, which is evaluated in the function body. Thus, for <code>time.spacing = NULL</code> the animation has a duration of approximately 5 seconds. In the other case, <code>sleep</code> is the duration of the artificial pause between two time points.
legend.opts	either a list of arguments passed to the <code>legend</code> function or <code>NULL</code> (or <code>NA</code>), in which case no legend will be plotted. All necessary arguments have sensible defaults and need not be specified, i.e.\ <pre>x: "topright" legend: c("susceptible", "infectious", "removed") pch: same as argument pch of the main function col: same as argument col of the main function</pre>
timer.opts	either a list of arguments passed to the <code>legend</code> function or <code>NULL</code> (or <code>NA</code>), in which case no timer will be plotted. All necessary arguments have sensible defaults and need not be specified, i.e.\ <pre>x: "bottomright" title: "time" box.lty: 0 adj: c(0.5,0.5) inset: 0.01 bg: "white"</pre> <p>Note that the argument <code>legend</code>, which is the current time of the animation, can not be modified.</p>
end	ending time of the animation in case of <code>time.spacing</code> not being <code>NULL</code> . By default (<code>NULL</code>), time stops after the last event.
generate.snapshots	<code>NULL</code> (the default) or a list of arguments passed to function <code>dev.print</code> , which then is executed at each time point of the grid defined by <code>time.spacing</code> . Note that this only works with <code>time.spacing</code> not being <code>NULL</code> . Essentially, this is used for saving the produced snapshots to files, e.g.\ <pre>generate.snapshots = list(device=pdf, file=quote(paste("epidemic_", sprintf(form,t0), ".pdf", sep="")))</pre> will store the animation steps in pdf-files in the current working directory, where the file names each end with the time point represented by the corresponding plot. Because the variables <code>t0</code> and <code>form</code> are evaluated inside the function the file argument is quoted.
...	further graphical parameters passed to the basic call of <code>plot</code> , e.g.\ <code>las</code> , <code>cex.axis</code> (etc.) and <code>mgp</code> .

Author(s)

Sebastian Meyer

See Also

[summary.epidata](#) for the data, on which the plot is based. [plot.epidata](#) for plotting the evolution of an epidemic by the numbers of susceptible, infectious and removed individuals.

Examples

```

data("foepidata")
s <- summary(foepidata)

# plot the ordering of the events only
animate(s) # or animate(foepidata)

# with timer
animate(s, time.spacing = 0.1)

```

twinSIR_epidata_intersperse

Impute Blocks for Extra Stops in "epidata" Objects

Description

This function modifies an object inheriting from class "epidata" such that it features the specified stop time points. For this purpose, the time interval in the event history into which the new stop falls will be splitted up into two parts, one block for the time period until the new stop – where no infection or removal occurs – and the other block for the time period from the new stop to the end of the original interval.

Main application is to enable the use of knots in twinSIR, which are not existing stop time points in the "epidata" object.

Usage

```
intersperse(epidata, stoptimes)
```

Arguments

epidata	an object inheriting from class "epidata".
stoptimes	a numeric vector of time points inside the observation period of the epidata.

Value

an object of the same class as epidata with additional time blocks for any new stoptimes.

Author(s)

Sebastian Meyer

Examples

```

data("foepidata")
subset(foepidata, start < 25 & stop > 25, select = 1:7)
nrow(foepidata)
moreStopsEpi <- intersperse(foepidata, c(25,75))
nrow(moreStopsEpi)
subset(moreStopsEpi, stop == 25 | start == 25, select = 1:7)

```

Description

Functions for plotting the evolution of epidemics. The `plot` methods for classes `"epidata"` and `"summary.epidata"` plots the numbers of susceptible, infectious and recovered (= removed) individuals by step functions along the time axis. The function `stateplot` shows individual state changes along the time axis.

Usage

```
## S3 method for class 'summary.epidata'
plot(x, lty = c(2, 1, 3), lwd = 1, col = 1, col.hor = col,
     col.vert = col, xlab = "Time", ylab = "Number of individuals",
     xlim = NULL, ylim = NULL, legend.opts = list(), do.axis4 = NULL,
     panel.first = grid(), rug.opts = list(),
     which.rug = c("infections", "removals", "susceptibility", "all"), ...)
## S3 method for class 'epidata'
plot(x, ...)

stateplot(x, id, ...)
```

Arguments

- | | |
|---|--|
| <code>x</code> | an object inheriting from class <code>"epidata"</code> or <code>"summary.epidata"</code> . In the former case, its summary is calculated and the function continues as in the latter case. The <code>plot</code> method for class <code>"epidata"</code> is a simple wrapper for <code>plot.summary.epidata</code> implemented as <code>plot(summary(x, ...))</code> . |
| <code>lty</code> , <code>lwd</code> | vectors of length 3 containing the line types and widths, respectively, for the numbers of susceptible, infectious and removed individuals (in this order). By default, all lines have width 1 and the line types are dashed (susceptible), solid (infectious) and dotted (removed), respectively. To omit the drawing of a specific line, just set the corresponding entry in <code>lty</code> to 0. The vectors are recycled if necessary. For information about the different <code>lty</code> and <code>lwd</code> codes, see the help pages of par . |
| <code>col</code> , <code>col.hor</code> , <code>col.vert</code> | vectors of length 3 containing the line colors for the numbers of susceptible, infectious and removed individuals (in this order). <code>col.hor</code> defines the color for the horizontal parts of the step function, whilst <code>col.vert</code> defines the color for its vertical parts. The argument <code>col</code> is just short for <code>col.hor = col</code> and <code>col.vert = col</code> . By default, all lines are completely drawn in black. The vectors are recycled if necessary. For information about the possible values of <code>col</code> , see the help pages of par . |
| <code>xlab</code> , <code>ylab</code> | axis labels, default to <code>"Time"</code> and <code>"Number of individuals"</code> , respectively. |

<code>xlim, ylim</code>	the x and y limits of the plot in the form <code>c(xmin, xmax)</code> and <code>c(ymin, ymax)</code> , respectively. By default, these are chosen adequately to fit the time range of the epidemic and the number of individuals.
<code>legend.opts</code>	either a list of arguments passed to the <code>legend</code> function or <code>NULL</code> (or <code>NA</code>), in which case no legend will be plotted. All necessary arguments have sensible defaults and need not be specified, i.e.\ <code>x: "topright"</code> \ <code>legend: c("susceptible", "infectious", "removed")</code> \ <code>lty: same as argument lty of the main function</code> \ <code>lwd: same as argument lwd of the main function</code> \ <code>col: same as argument col.hor of the main function</code> \ <code>bty: "n"</code>
<code>do.axis4</code>	logical indicating if the final numbers of susceptible and removed individuals should be indicated on the right axis. The default <code>NULL</code> means <code>TRUE</code> , if x represents a SIR epidemic and <code>FALSE</code> otherwise, i.e. if the epidemic is SI, SIS or SIRS.
<code>panel.first</code>	an expression to be evaluated after the plot axes are set up but before any plotting takes place. By default, a standard grid is drawn.
<code>rug.opts</code>	either a list of arguments passed to the function <code>rug</code> or <code>NULL</code> (or <code>NA</code>), in which case no rug will be plotted. By default, the argument <code>ticksize</code> is set to 0.02 and <code>quiet</code> is set to <code>TRUE</code> . Note that the argument <code>x</code> , which contains the locations for the rug is fixed internally and can not be modified. The argument <code>which.rug</code> (see below) determines the locations to mark.
<code>which.rug</code>	By default, tick marks are drawn at the time points of infections. Alternatively, one can choose to mark only "removals", "susceptibilities" (i.e. state change from R to S) or "all" events.
<code>id</code>	single character string or factor of length 1 specifying the individual for which the stateplot should be established.
<code>...</code>	For <code>plot.summary.epidata</code> : further graphical parameters passed to <code>plot</code> , lines and axis, e.g.\ <code>main</code> , <code>las</code> , <code>cex.axis</code> (etc.) and <code>mgp</code> . For <code>plot.epidata</code> : arguments passed to <code>plot.summary.epidata</code> . For <code>stateplot</code> : arguments passed to <code>plot.stepfun</code> or <code>plot.function</code> (if <code>id</code> had no events during the observation period). By default, <code>xlab="time"</code> , <code>ylab="state"</code> , <code>xlim=attr(x, "timeRange")</code> , <code>xaxs="i"</code> and <code>do.points=FALSE</code> .

Value

`plot.summary.epidata` (and `plot.epidata`) invisibly returns the matrix used for plotting, which contains the evolution of the three counters.

`stateplot` invisibly returns the function, which was plotted, typically of class "stepfun", but maybe of class "function", if no events have been observed for the individual in question (then the function always returns the initial state). The vertical axis of `stateplot` can range from 1 to 3, where 1 corresponds to Susceptible, 2 to *Infectious* and 3 to *Removed*.

Author(s)

Sebastian Meyer

See Also

[summary.epidata](#) for the data, on which the plots are based. [animate.epidata](#) for the animation of epidemics.

Examples

```
data("fooePIData")
s <- summary(fooePIData)

# evolution of the epidemic
par(las = 1)
plot(s)

# stateplot
stateplot(s, id = "15", main = "Some individual event paths")
stateplot(s, id = "1", add = TRUE, col = 2)
stateplot(s, id = "20", add = TRUE, col = 3)
legend("topright", legend = c(15, 1, 20), title = "id", lty = 1, col = 1:3,
      inset = 0.1)
```

twinSIR_epidata_summary

Summarizing an Epidemic

Description

The [summary](#) method for class "[epidata](#)" gives an overview of the epidemic. Its [print](#) method shows the type of the epidemic, the time range, the total number of individuals, the initially and never infected individuals and the size of the epidemic. An excerpt of the returned counters data frame is also printed (see the Value section below).

Usage

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

## S3 method for class 'summary.epidata'
print(x, ...)
```

Arguments

object	an object inheriting from class " epidata ".
x	an object inheriting from class " summary.epidata ", i.e. an object returned by the function summary.epidata .
...	unused (argument of the generic).

Value

A list with the following components:

type	character string. Compartmental type of the epidemic, i.e.\ one of "SIR", "SI", "SIS" or "SIRS".
size	integer. Size of the epidemic, i.e.\ the number of initially susceptible individuals, which became infected during the course of the epidemic.
initiallyInfected	factor (with the same levels as the id column in the "epidata" object). Set of initially infected individuals.
neverInfected	factor (with the same levels as the id column in the "epidata" object). Set of never infected individuals, i.e.\ individuals, which were neither initially infected nor infected during the course of the epidemic.
coordinates	numeric matrix of individual coordinates with as many rows as there are individuals and one column for each spatial dimension. The row names of the matrix are the ids of the individuals.
byID	data frame with time points of infection and optionally removal and re-susceptibility (depending on the type of the epidemic) ordered by id. If an event was not observed, the corresponding entry is missing.
counters	data frame containing all events (S, I and R) ordered by time. The columns are time, type (of event), corresponding id and the three counters nSusceptible, nInfectious and nRemoved. The first row additionally shows the counters at the beginning of the epidemic, where the type and id column contain missing values.

Author(s)

Sebastian Meyer

See Also

[as.epidata](#) for generating objects of class "epidata".

Examples

```
data("fooePIData")
s <- summary(fooePIData)
s          # uses the print method for summary.epidata
names(s)  # components of the list 's'

# positions of the individuals
plot(s$coordinates)

# events by id
head(s$byID)
```

twinSIR_intensityPlot *Plotting Paths of Infection Intensities*

Description

Function to plot the values of the total infection intensity, its epidemic proportion and its endemic proportion along the evolution of the epidemic.

Usage

```
intensityPlot(x, type = c("overall", "individual"),
             what = c("epidemic proportion", "endemic proportion",
                    "total intensity"),
             theta = NULL, plot = TRUE, add = FALSE, rug.opts = list(), ...)

## S3 method for class 'twinSIR'
plot(x, type = c("overall", "individual"),
     what = c("epidemic proportion", "endemic proportion", "total intensity"),
     theta = coef(x), plot = TRUE, add = FALSE, rug.opts = list(), ...)
```

Arguments

x	an object of class " <code>simEpidata</code> " or " <code>twinSIR</code> ".
type	single character: "overall" or "individual". Partial matching is applied. Determines whether lines for all individual infection intensities should be drawn or their sum only.
what	single character: "epidemic proportion", "endemic proportion" or "total intensity". Partial matching is applied. Determines whether to plot the path of the total intensity $\lambda(t)$ or its epidemic or endemic proportions $\frac{e(t)}{\lambda(t)}$ or $\frac{h(t)}{\lambda(t)}$.
theta	numeric vector of model coefficients. If x is of class "twinSIR", then <code>theta = c(alpha, beta)</code> , where <code>beta</code> consists of the coefficients of the piecewise constant log-baseline function and the coefficients of the endemic (cox) predictor. If x is of class "simEpidata", then <code>theta = c(alpha, 1, betarest)</code> , where 1 refers to the (true) log-baseline used in the simulation and <code>betarest</code> is the vector of the remaining coefficients of the endemic (cox) predictor. The default (NULL) means that the fitted or true parameters, respectively, will be used.
plot	logical indicating if a plot is desired, defaults to TRUE. Otherwise, only the data of the plot will be returned. Especially with <code>type = "individual"</code> and many individuals one might e.g. consider to plot a subset of the individual intensity paths only or do some further calculations/analysis of the infection intensities.
add	logical. If TRUE, plots are added to current one, using lines.
rug.opts	either a list of arguments passed to the function <code>rug</code> or NULL (or NA), in which case no rug will be plotted. By default, the argument <code>ticksize</code> is set to 0.02 and <code>quiet</code> is set to TRUE. Note that the argument x, which contains the locations for the rug is fixed internally and can not be modified. The locations of the rug are the time points of infections.

... further graphical parameters passed to the function `matplot`, e.g. `lty`, `lwd`, `col`, `xlab`, `ylab` and `main`. Note that the `matplot` arguments `x`, `y`, `type` and `add` are implicit and can not be specified here.

Value

numeric matrix with the first column "stop" and as many rows as there are "stop" time points in the event history `x`. The other columns depend on the argument `type`: if `type = "overall"` there is only one other column named `what`, which contains the values of `what` at the respective "stop" time points. Otherwise, if `type = "individual"`, there is one column for each individual, each of them containing the individual `what` at the respective "stop" times points.

Author(s)

Sebastian Meyer

References

Höhle, M. (2009), Additive-Multiplicative Regression Models for Spatio-Temporal Epidemics, Accepted for publication in the Biometrical Journal.

Höhle, Michael (2008) Spatio-temporal epidemic modelling using additive-multiplicative intensity models. *Ludwig-Maximilians-Universität, Department of Statistics: Technical Reports*, No. 41. Available at <http://epub.ub.uni-muenchen.de/6366/>.

See Also

`twinSIR` or Höhle (2008) for a more detailed description of the intensity model.

Examples

```
data("foeepidata")
data("foefit")

# an overview of the evolution of the epidemic
plot(foeepidata)

# overall total intensity
plot(foefit, what="total")

# overall epidemic proportion
head(plot(foefit, what="epidemic"))

# add the inverse overall endemic proportion = 1 - epidemic proportion
head(plot(foefit, what="endemic", add=TRUE, col=2))
legend("right", legend="endemic proportion \n(= 1 - epidemic proportion)",
      lty=1, col=2, bty="n")

# individual intensities
tmp <- plot(foefit, type="individual", what="total",
           col=rgb(0,0,0,alpha=if(getRversion() < "2.7.0") 1 else 0.1),
           main=expression("Individual infection intensities" *

```

```

lambda[i](t) == Y[i](t) %.% (e[i](t) + h[i](t)))
str(tmp)

# and only for individuals 3 and 99
matplot(x= tmp[,1], y=tmp[,1+c(3,99)], type="S", ylab="infection intensity",
        xlab="time", main=expression("Paths of the infection intensities" *
        lambda[3](t) * " and " * lambda[99](t)))
legend("topright", legend=paste("Individual", c(3,99)), col=c(1,2), lty=c(1,2))

```

twinSIR_methods

Print, Summary and Extraction Methods for "twinSIR" Objects

Description

Besides print and summary methods there are also some standard extraction methods defined for objects of class "twinSIR": `coef`, `vcov`, `logLik` and especially `AIC` and `extractAIC`, which extract Akaike's Information Criterion. Note that special care is needed, when fitting models with parameter constraints such as the epidemic effects α in twinSIR models. Parameter constraints reduce the average increase in the maximized loglikelihood - thus the penalty for constrained parameters should be smaller than the factor 2 used in the ordinary definition of AIC. To this end, these two methods offer the calculation of the so-called one-sided AIC (OSAIC).

Usage

```

## S3 method for class 'twinSIR'
print(x, digits = max(3, getOption("digits") - 3), ...)
## S3 method for class 'twinSIR'
summary(object,
        correlation = FALSE, symbolic.cor = FALSE, ...)

## S3 method for class 'twinSIR'
AIC(object, ..., k = 2, one.sided = NULL, nsim = 1e3)
## S3 method for class 'twinSIR'
extractAIC(fit, scale = 0, k = 2, one.sided = NULL,
        nsim = 1e3, ...)

## S3 method for class 'twinSIR'
coef(object, ...)
## S3 method for class 'twinSIR'
vcov(object, ...)
## S3 method for class 'twinSIR'
logLik(object, ...)

```

Arguments

`x`, `object`, `fit` an object of class "twinSIR".
`digits` integer, used for number formatting with `signif()`. Minimum number of significant digits to be printed in values.

correlation	logical. if TRUE, the correlation matrix of the estimated parameters is returned and printed.
symbolic.cor	logical. If TRUE, print the correlations in a symbolic form (see <code>symnum</code>) rather than as numbers.
...	For the summary method: arguments passed to <code>extractAIC.twinSIR</code> . For the AIC method, optionally more fitted model objects. For the <code>print</code> , <code>extractAIC</code> , <code>coef</code> , <code>vcov</code> and <code>logLik</code> methods: unused (argument of the generic).
k	numeric specifying the "weight" of the <i>penalty</i> to be used; in an unconstrained fit $k = 2$ is the classical AIC.
one.sided	logical or NULL (the default). Determines if the one-sided AIC should be calculated instead of using the classical penalty $k \times \text{edf}$. The default value NULL chooses classical AIC in the case of an unconstrained fit and one-sided AIC in the case of constraints. The type of the fit can be seen in <code>object\$method</code> (or <code>fit\$method</code> respectively), where "L-BFGS" means constrained optimization.
nsim	number of simulations to use for determining the weights in the OSAIC formula when there are more than two epidemic covariates in the fit. Defaults to 1000 samples.
scale	unused (argument of the generic).

Details

The `print` and `summary` methods allow the compact or comprehensive representation of the fitting results, respectively. The former only prints the original function call, the estimated coefficients and the maximum log-likelihood value. The latter prints the whole coefficient matrix with standard errors, z- and p-values (see `printCoefmat`), and additionally the number of infections per log-baseline interval, the (one-sided) AIC and the number of log-likelihood evaluations. They both append a big "WARNING", if the optimization algorithm did not converge.

The two AIC functions differ only in that `AIC` can take more than one fitted model object and that `extractAIC` always returns the number of parameters in the model (`AIC` only does with more than one fitted model object).

Concerning the choice of one-sided AIC: parameter constraints – such as the non-negative constraints for the epidemic effects α in `twinSIR` models – reduce the average increase in the maximized loglikelihood. Thus, the penalty for constrained parameters should be smaller than the factor 2 used in the ordinary definition of AIC. One-sided AIC (OSAIC) suggested by Hughes and King (2003) is such a proposal when p out of $k = p + q$ parameters have non-negative constraints:

$$OSAIC = -2l(\theta, \tau) + 2 \sum_{g=0}^p w(p, g)(k - p + g)$$

where $w(p, g)$ are p -specific weights. For more details see Section 5.2 in Höhle (2008).

Value

See the documentation for the generic functions `AIC` and `extractAIC`, respectively.

Author(s)

Michael Höhle and Sebastian Meyer

References

Hughes A, King M (2003) Model selection using AIC in the presence of one-sided information. *Journal of Statistical Planning and Inference* **115**, pp. 397–411.

Höhle, Michael (2008) Spatio-temporal epidemic modelling using additive-multiplicative intensity models. *Ludwig-Maximilians-Universität, Department of Statistics: Technical Reports*, No. 41. Available at <http://epub.ub.uni-muenchen.de/6366/>.

Examples

```
data("foofit")

foofit

coef(foofit)
vcov(foofit)
logLik(foofit)

summary(foofit, correlation = TRUE, symbolic.cor = TRUE)

# AIC or OSAIC
AIC(foofit)
AIC(foofit, one.sided = FALSE)
extractAIC(foofit)
extractAIC(foofit, one.sided = FALSE)

# with BIC-like penalty weight
AIC(foofit, k = log(nlevels(foofit$model$survs$id)))

# just as a stupid example for the use of AIC with multiple fits
foofit2 <- foofit
AIC(foofit, foofit2) # 2nd column should actually be named "OSAIC" here
```

twinSIR_profile

Profile Likelihood Computation and Confidence Intervals

Description

Function to compute estimated and profile likelihood based confidence intervals. Computations might be cumbersome!

Usage

```
## S3 method for class 'twinSIR'
profile(fitted, profile, alpha = 0.05,
       control = list(fnscale = -1, factr = 10, maxit = 100), ...)
```

Arguments

fitted	an object of class "twinSIR".
profile	a list with elements being numeric vectors of length 4. These vectors must have the form <code>c(index, lower, upper, gridsize)</code> . index: index of the parameter to be profiled in the vector <code>coef(fitted)</code> . lower, upper: lower/upper limit of the grid on which the profile log-likelihood is evaluated. Can also be NA in which case lower/upper equals the lower/upper bound of the respective 0.3 % Wald confidence interval ($\pm 3 \cdot se$). gridsize: grid size of the equally spaced grid between lower and upper. Can also be 0 in which case the profile log-likelihood for this parameter is not evaluated on a grid.
alpha	$(1 - \alpha)\%$ profile likelihood based confidence intervals are computed. If $\alpha \leq 0$, then no confidence intervals are computed.
control	control object to use in <code>optim</code> for the profile log-likelihood computations.
...	unused (argument of the generic).

Value

list with profile log-likelihood evaluations on the grid and highest likelihood and wald confidence intervals. The argument `profile` is also returned.

Author(s)

Michael Höhle

Examples

```
data("foofit")
# the following call takes a while
## Not run:
prof <- profile(foofit, list(c(1,0,0.05,5), c(3,NA,NA,0), c(4, NA, NA, 10)))
prof

## End(Not run)
```

twinSIR_simulation *Simulation of Epidemic Data*

Description

This function simulates the infection (and removal) times of an epidemic. Besides the classical SIR type of epidemic, also SI, SIRS and SIS epidemics are supported. Simulation works via the conditional intensity of infection of an individual, given some (time varying) endemic covariates and/or some distance functions (epidemic components) as well as the fixed positions of the individuals. The lengths of the infectious and removed periods are generated following a pre-specified function (can be deterministic).

The `simulate` method for objects of class `"twinSIR"` simulates new epidemic data using the model and the parameter estimates of the fitted object.

Usage

```
simEpidata(formula, data, id.col, I0.col, coords.cols, subset,
           beta, h0, f = list(), alpha, infPeriod,
           remPeriod = function(ids) rep(Inf, length(ids)),
           end = Inf, trace = FALSE, .allocate = 500L)

## S3 method for class 'twinSIR'
simulate(object, nsim = 1, seed = 1,
         infPeriod = NULL, remPeriod = NULL,
         end = diff(range(object$intervals)), trace = FALSE, .allocate = 500L,
         data = object$data, ...)
```

Arguments

formula	an object of class <code>"formula"</code> (or one that can be coerced to that class): a symbolic description of the intensity model to be estimated. The details of model specification are given under Details.
data	<p>a data.frame containing the variables in formula and the variables specified by <code>id.col</code>, <code>I0.col</code> and <code>coords.col</code> (see below). It represents the "history" of the endemic covariates to use for the simulation. The form is similar to and can be an object of class <code>"epidata"</code>. The simulation period is splitted up into <i>consecutive</i> intervals of constant endemic covariables. The data-frame consists of a block of N (number of individuals) rows for each of those time intervals (all rows in a block share the same start and stop values... therefore the name "block"), where there is one row per individual in the block. Each row describes the (fixed) state of the endemic covariates of the individual during the time interval given by the start and stop columns (specified through the lhs of formula).</p> <p>For the <code>simulate</code> method of class <code>"twinSIR"</code> this should be the object of class <code>"epidata"</code> used for the fit. This is a part of the return value of the function <code>twinSIR</code>, if called with argument <code>keep.data</code> set to <code>TRUE</code>.</p>
id.col	<p>only if data does not inherit from <code>epidata</code>: single index of the id column in data. Can be numeric (by column number) or character (by column name). The id column identifies the individuals in the data-frame. It will be converted to a factor variable and its levels serve also to identify individuals as argument to the <code>infPeriod</code> function.</p>
I0.col	<p>only if data does not inherit from <code>epidata</code>: single index of the I0 column in data. Can be numeric (by column number), character (by column name) or <code>NULL</code>.</p> <p>The I0 column indicates if an individual is initially infectious, i.e. it is already infectious at the beginning of the first time block. Setting <code>I0.col = NULL</code> is short for "there are no initially infectious individuals". Otherwise, the variable must be logical or in 0/1-coding. As this variable is constant over time the initially infectious individuals are derived from the first time block only.</p>

coords.cols	<p>only if data does not inherit from epidata: indexes of the coords columns in data. Can be a numeric (by column number), a character (by column name) vector or NULL.</p> <p>These columns contain the coordinates of the individuals. It must be emphasized that the functions in this package currently assume <i>fixed positions</i> of the individuals during the whole epidemic. Thus, an individual has the same coordinates in every block. For simplicity, the coordinates are derived from the first time block only. The epidemic covariates are calculated based on the euclidian distance between the individuals, see f.</p>
subset	an optional vector specifying a subset of the covariate history to be used in the simulation.
beta	numeric vector of length equal the number of endemic (cox) terms on the rhs of formula. It contains the effects of the endemic predictor (excluding the log-baseline h0, see below) in the same order as in the formula.
h0	<i>either</i> a single number to specify a constant baseline hazard (equal to $\exp(h0)$) <i>or</i> a list of functions named exact and upper. In the latter case, h0\$exact is the true log-baseline hazard function and h0\$upper is a <i>piecewise constant upper bound</i> for h0\$exact. The function h0\$upper must inherit from stepfun with right=FALSE. Theoretically, the intensity function is left-continuous, thus right=TRUE would be adequate, but in the implementation, when we evaluate the intensity at the knots (change points) of h0\$upper we need its value for the subsequent interval.
f	<p>a <i>named</i> list of distance functions or list() (the default), if no epidemic component is desired (if additionally infPeriod (see below) always returns Inf, then one simulates from the Cox model). The functions must interact element-wise on a (distance) matrix so that - for a matrix D - f[[m]](D) results in a matrix. A simple example is function(u) {u <= 1}, which indicates if the euclidian distance between the individuals is smaller than or equal to 1. To ensure that an individual does not influence itself, the distance to itself is defined as Inf. Consequently, all of the distance functions must have the property f[[m]](Inf) = 0. The names of the functions will be the names of the epidemic variables in the resulting data-frame. So, the names should not coincident with names of endemic variables. The value of such an epidemic variable is computed as follows: $I(t)$ denotes the set of infectious individuals just before time t and s_i the coordinate vector of individual i. For individual i at time t the epidemic component m has the value $\sum_{j \in I(t)} f_m(\ s_i - s_j\)$</p>
alpha	numeric vector of length equal the number of epidemic terms, i.e. the number of distance functions in f. It contains the effects of the epidemic predictor in the same order as the distance functions in f or, if names are supplied, matching to the distance functions will be done by name.
infPeriod	a function generating lengths of infectious periods. It should take one parameter (e.g. ids), which is a character vector of id's of individuals, and return appropriate infection periods for those individuals. Therefore, the value of the function should be of length length(ids). For example, for independent and identically distributed infection periods following $Exp(1)$, the generating function is

function(ids) rexp(length(ids), rate=1). For a constant infectious period of length c , it is sufficient to set `function(x) {c}`. For the `simulate` method of class "twinSIR" only, this can also be NULL (the default), which means that the observed infectious periods of infected individuals are re-used when simulating a new epidemic and individuals with missing infectious periods (i.e. infection and recovery was not observed) are attributed to the mean observed infectious period.

Note that it is even possible to simulate an SI-epidemic by setting `infPeriod = function(x) {Inf}`: once an individual became infected it spreads the disease forever, i.e. it will never be removed.

remPeriod	a function generating lengths of removal periods. Per default, once an individual was removed it will stay in this state forever (Inf). Therefore, it will not become at-risk (S) again and re-infections are not possible. Alternatively, always returning 0 as length of the removal period corresponds to a SIS epidemic. Any other values correspond to SIRS.
end	a single positive numeric value specifying the time point at which the simulation should be forced to end. By default, this is Inf, i.e. the simulation continues until there is no susceptible individual left. For the <code>simulate</code> method of class "twinSIR" the default is to have equal simulation and observation periods.
trace	logical (or integer) indicating if (or how often) the sets of susceptible and infected individuals as well as the rejection indicator (of the rejection sampling step) should be cated. Defaults to FALSE.
.allocate	number of blocks to initially allocate for the event history; defaults to 500, i.e. 500*N rows. Each time the simulated epidemic exceeds the allocated space, the event history will be enlarged by .allocate blocks.
object	an object of class "twinSIR". This must contain the original data used for the fit (see data).
nsim	number of epidemics to simulate. Defaults to 1.
seed	an integer that will be used in the call to <code>set.seed</code> before simulating the epidemics.
...	unused (argument of the generic).

Details

A model is specified through the formula, which has the form `cbind(start, stop) ~ cox(endemicVar1) * cox(endemicVar2)`, i.e. the right hand side has the usual form as in `lm`, but all variables are marked as being endemic by the special function `cox`. The effects of those predictor terms are specified by `beta`. The left hand side of the formula denotes the start and stop columns in data. This can be omitted, if data inherits from class "epidata" in which case `cbind(start, stop)` will be used. The epidemic model component is specified by the parameter `f` (and by the epidemic effects `alpha`).

The simulation algorithm used is *Ogata's modified thinning*. For details, see Höhle (2008), Section 4.

Value

An object of class "simEpidata", which is a data.frame with the columns "id", "start", "stop", "atRiskY", "event", "Revent" and the coordinate columns (with the original names from data), which are all obligatory. These columns are followed by all the variables appearing on the rhs of the formula. Last but not least, the generated columns with epidemic variables corresponding to the functions in the list f are appended, if `length(f) > 0`. Note that objects of class "simEpidata" also inherit from class "epidata", thus all "epidata" methods can be applied.

The data.frame is given the additional *attributes*

"eventTimes"	numeric vector of infection time points (sorted chronologically).
"timeRange"	numeric vector of length 2: <code>c(min(start), max(stop))</code> .
"coords.cols"	numeric vector containing the column indices of the coordinate columns in the resulting data-frame.
"f"	this equals the argument f.
"config"	a list with elements <code>h0 = h0\$exact</code> , beta and alpha.
call	the matched call.
terms	the terms object used.

Author(s)

Sebastian Meyer and Michael Höhle

References

Höhle, M. (2009), Additive-Multiplicative Regression Models for Spatio-Temporal Epidemics, Accepted for publication in the Biometrical Journal.

Höhle, Michael (2008) Spatio-temporal epidemic modelling using additive-multiplicative intensity models. *Ludwig-Maximilians-Universität, Department of Statistics: Technical Reports*, No. 41. Available at <http://epub.ub.uni-muenchen.de/6366/>.

See Also

The `plot` method and the function `animate.epidata` for plotting and animation of epidemic data, respectively. `intensityPlot` for plotting the path of the infection intensity.

Function `twinSIR` for fitting spatio-temporal epidemic intensity models to epidemic data.

Examples

```
set.seed(1234)
# Generate a data frame containing a hypothetical population with 100 individuals
n <- 100
pos <- matrix(rnorm(n*2), ncol=2, dimnames=list(NULL, c("x", "y")))
pop <- data.frame(id=1:n, x=pos[,1], y=pos[,2],
                 gender=sample(0:1, n, replace=TRUE),
                 I0col=rep(0,n), start=rep(0,n), stop=rep(Inf,n))

epi <- simEpidata(cbind(start,stop) ~ cox(gender),
```

```

        data = pop,
        id = "id", I0.col = "I0col", coords.cols = c("x","y"),
        beta = c(-3), h0 = -2, alpha = c(B1 = 0.1),
        f = list(B1 = function(u) u <= 1),
        infPeriod = function(ids) rexp(length(ids), rate=1))
plot(epi)

# load data of an observed epidemic
data("fooePIData")
summary(fooePIData)

# simulate a new evolution of the epidemic
simepi <- simEpidata(cbind(start, stop) ~ cox(z1) + cox(z1):cox(z2),
  data = fooePIData,
  beta = c(1,0.5), h0 = -7, alpha = c(B2 = 0.1, B1 = 0.05),
  f = list(B1 = function(u) u<=1, B2 = function(u) u>1 & is.finite(u)),
  infPeriod = function(ids) rexp(length(ids), rate=1), trace = FALSE)
summary(simepi)
plot(simepi)
## Not run:
animate(simepi)

## End(Not run)
intensityPlot(simepi)

# load a fitted model object, which must contain the original data
# (use 'keep.data = TRUE' in the call of 'twinSIR')
data("foofit")
foofit

# plot original epidemic
plot(foofit$data)

## simulate a new epidemic using the model and parameter estimates of 'foofit'
## and set simulation period = observation period
# with observed infPeriods:
simfitepi1 <- simulate(foofit, nsim = 1)[[1]]
plot(simfitepi1)
# with new infPeriods:
simfitepi2 <- simulate(foofit, nsim = 1,
  infPeriod=function(ids) rexp(length(ids), rate=0.3))[1]]
plot(simfitepi2)

```

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