Package 'hte'

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R topics documented:

`hte-package` *Hospital transmission estimation*

Description

The **hte** package ...

Author(s)

Aaron A. King

`Bernoulli_filter` *Bernoulli filter*

Description

Filter the individual patient data with given forces of infection, recovery rates, and test characteristics.

Usage

```
Bernoulli_filter(data, lambda, gamma, theta)

Bfilter(data, theta)
```

Arguments

`data`	data set
`lambda`	unit-specific force of infection
`gamma`	unit-specific recovery rate
`theta`	list of parameters

Details

`Bernoulli_filter` runs a Bernoulli filter, updating the expected prevalence. It returns the log likelihood, occupancy, and expected prevalences.

`Bfilter` uses an alternative algorithm.

Value

`Bernoulli_filter` returns a `tibble` containing the expected prevalences (for both isolated and un-isolated patients), unit occupancy, force of infection, and conditional log likelihood for each unit at each event time. The sum of the log likelihood column (`logLik`) is the log likelihood of the data.

`Bfilter` returns the log likelihood of the furnished data.

Examples

```
library(tidyverse)

set.seed(626292345)

fake_data |>
  arrange(patient,time) -> dat

theta <- list(
  lambda=c(out=0,A=0.01,B=0.1,C=0.2,D=0.3,E=0.5),
  gamma=c(out=0.1,A=0.1,B=0.1,C=0.1,D=0.1,E=0.1),
```

```
  p0=0.2,
  isol_factor=0.1,
  alpha=0.05,
  beta=0.2
)

dat |>
  Bfilter(theta) -> ll1
sum(ll1)

dat |>
  Bernoulli_filter(
    lambda=theta$lambda,
    gamma=theta$gamma,
    theta
  ) -> f
f |> filter(logLik!=0) |> pull(logLik) -> ll2
sum(ll2)

f

f |>
  select(unit,time,prev_i,prev_u) |>
  pivot_longer(c(prev_i,prev_u)) |>
  group_by(unit) |>
  ## prevalence is not estimated outside the hospital
  filter(!all(is.na(value))) |>
  ungroup() |>
  ggplot(aes(x=time,color=name,y=value))+
  geom_line(alpha=0.5)+
  scale_color_manual(values=c(prev_i="blue",prev_u="red"))+
  facet_grid(unit~.,labeller=label_both)+
  labs(y="prevalence")+
  theme_bw()
```

`coal_last` *Coalesce with last*

Description

Fills NA with previous non-NA.

Usage

```
coal_last(x)
```

Arguments

x	vector

fake_data *Fake hospital movement, testing, and isolation data*

Description

A simulated outbreak

Details

Data are generated using the default settings of `simuldat`.

The data were generated by:

```
set.seed(339613584)
simuldat(verbose=TRUE) -> fake_data
save(fake_data,file="fake_data.rda")
```

See Also

More on simulated data: `simuldat()`

Examples

```
library(tidyverse)
library(lubridate)

## Examine the data:
fake_data

## Verify certain conditions hold:
stopifnot(
  `admission condition violation`=fake_data |>
    group_by(patient,visit) |> slice_head() |>
    filter(event!="admit") |> nrow()==0,
  `discharge condition violation`=fake_data |>
    group_by(patient,visit) |> slice_tail() |>
    filter(event!="discharge",event!="stop") |> nrow()==0,
  `unit violation`=fake_data |> filter(is.na(unit)) |> nrow()==0,
  `event violation`=fake_data |> filter(is.na(event)) |> nrow()==0
)

fake_data |>
  mutate(
    time=as.numeric(
      as.duration(
        interval(date,start="2000-01-01T00:00:00+0000")
      ),
      units="day"
    )
  ) -> fake_data
```

```
fake_data |>
  group_by(patient,visit) |>
  summarize(dur=max(time)-min(time)) |>
  ungroup() |>
  group_by(patient) |>
  summarize(dur=sum(dur)) |>
  ggplot(aes(x=log10(dur)))+
  geom_histogram(bins=20)+
  labs(title="total duration of hospitalization")+
  theme_bw()

fake_data |>
  group_by(patient,visit) |>
  summarize(dur=max(time)-min(time)) |>
  ungroup() |>
  ggplot(aes(x=log10(dur)))+
  geom_histogram(bins=40)+
  labs(title="duration of hospital visit")+
  theme_bw()

fake_data |>
  filter(
    event!="test",
    event!="isolate",
    event!="release",
    event!="stop"
  ) |>
  group_by(patient,visit) |>
  arrange(time) |>
  mutate(dur=lead(time)-time) |>
  ungroup() |>
  filter(unit!="out",!is.na(dur)) |>
  ggplot(aes(x=log10(dur),fill=unit,group=unit))+
  geom_histogram(aes(y=after_stat(density)),bins=40)+
  facet_grid(unit~.,scales="free_y")+
  labs(title="duration of stay by unit")+
  theme_bw()

fake_data |>
  group_by(patient) |>
  summarize(ntest=sum(event=="test")) |>
  ungroup() |>
  ggplot(aes(x=ntest))+
  geom_histogram(binwidth=1,center=0)+
  labs(title="number of tests per patient")+
  theme_bw()

fake_data |>
  arrange(time) |>
  mutate(
    dn=case_when(
      event=="admit"~1L,
```

```
      event=="discharge"~-1L,
      TRUE~0L
    ),
    occ=cumsum(dn)
  ) |>
  ggplot(aes(x=date,y=occ))+
  geom_step()+
  labs(title="hospital occupancy")+
  theme_bw()

fake_data |>
  arrange(time) |>
  select(date,test.result=result,isol,infected) |>
  pivot_longer(c(test.result,isol,infected)) |>
  filter(!is.na(value)) |>
  ggplot(aes(x=date,y=value,color=name))+
  geom_point()+
  geom_smooth()+
  guides(color="none")+
  labs(
    title="infection and isolation status, test results",
    y=""
  )+
  facet_grid(name~.)+
  theme_bw()

fake_data |>
  filter(event=="test") |>
  mutate(
    interval=cut(time,breaks=72,ordered=TRUE)
  ) |>
  select(interval,time,infected,isol,result) |>
  pivot_longer(c(infected,isol,result)) |>
  group_by(name,interval) |>
  summarize(
    time=mean(time),
    prev=mean(value),
    n=n()
  ) |>
  ungroup() |>
  ggplot(aes(x=time,y=prev,group=name,fill=name))+
  geom_col(position="dodge")+
  labs(title="infection, isolation, and detection through time")+
  theme_bw()+
  theme(axis.text.x=element_text(angle=90))

fake_data |>
  filter(event=="test") |>
  select(infected,result) |>
  count(infected,result) |>
  group_by(infected) |>
  mutate(prob=n/sum(n)) |>
  ungroup()
```

`independent` *Independent infection model*

Description

Model under which each patient's trajectory of infection is independent, conditional on the force of infection.

Usage

```
indep_homog_objfun(params, data, est = character(0))

indep_unit_spec_objfun(params, data, est = character(0))
```

Arguments

`params`	named vector of parameters
`data`	patient movement, isolation, and testing data
`est`	names of parameters to estimate

Details

`indep_homog_objfun` is a stateful objective function for the independent model with a global lambda and gamma.

`indep_unit_spec_objfun` is a stateful objective function for the independent model with unit specific lambda, one gamma for inside the hospital, and one gamma outside the hospital.

See Also

More on the independent infection model: `simuldat()`

More on stateful objective functions: `stobfun()`, `transmission`

Examples

```
library(tidyverse)
library(lubridate)
library(pomp)
library(hte)

set.seed(626292345)

fake_data |>
  ## filter out tests prior to day 250
  filter(
    event!="test" | time < 250,
    time < 1000
  ) |>
```

```
  arrange(patient,time) -> dat

indep_homog_objfun(
  params=c(
    lambda=0.1,gamma=0.01,p0=0.1,
    isol_factor=0.2,alpha=0.02,beta=0.1
  ),
  est=c("lambda","gamma"),
  data=dat
) -> f

optim(
  par=log(c(0.1,0.01)),
  fn=f,
  control=list(reltol=1e-3)
) -> out
f(out$par)
coef(f)

indep_homog_objfun(
  params=coef(f),
  est=c("lambda"),
  data=dat
) -> g

log.lambda <- seq(log(0.001),to=log(1),length=10)
plot(exp(log.lambda),sapply(log.lambda,g),log='x')

theta <- coef(f)
indep_unit_spec_objfun(
  params=c(
    lambda=setNames(rep.int(theta["lambda"],6),unique(dat$unit)),
    gamma.out=unname(theta["gamma"]),
    theta[c("p0","gamma","alpha","beta","isol_factor")]
  ),
  est=c(
    "lambda.A","lambda.B","lambda.C","lambda.D","lambda.E","lambda.out",
    "gamma","gamma.out"
  ),
  data=dat
) -> h

## Not run:

optim(
  par=log(coef(h)[
    c("lambda.A","lambda.B","lambda.C","lambda.D","lambda.E","lambda.out",
      "gamma","gamma.out")
  ]),
  fn=h,
  control=list(reltol=1e-3)
) -> out
h(out$par)
```

```
coef(h)


## End(Not run)
```

---

simuldat *simuldat*

Description

simuldat simulates data representing the flow of a body of patients through a hospital over a specified window of time.

simul_patient simulates a single patient's history of movement, testing, isolation, and infection.

Usage

```
simuldat(
  nbeds = c(50, 60),
  arrival = 20,
  window = c("1999-12-31T23:59:59+0000", "2003-01-01T00:00:00+0000"),
 units = list(A = list(shape = 10, scale = 2/10), B = list(shape = 5, scale = 0.5/5), C
  = list(shape = 1, scale = 0.5/1), D = list(shape = 1, scale = 3/1), E = list(shape =
    0.2, scale = 8/0.2), out = list(shape = 0.5, scale = 300/0.5)),
  visits = list(size = 0.5, mu = 9),
  uperv = list(size = 1, mu = 0.5),
  min_dur = 1/24,
  testing_freq = c(A = NA, B = NA, C = 1/7, D = 1/7, E = 1/7, out = NA),
  isolation = list(on = 1/50, off = 1/50),
 infection = list(lambda = c(A = 0.01, B = 0.02, C = 0.001, D = 0.5, E = 0.1, out =
    0.05), gamma = 0.01, p0 = 0.1, isol_factor = 0.2),
  alpha = 0.02,
  beta = 0.1,
  verbose = getOption("verbose", TRUE)
)

simul_patient(
  patient,
  t0,
  tf,
  units,
  visits,
  uperv,
  min_dur,
  testing_freq,
  isolation,
  infection,
  alpha,
```

```
  beta
)

indep_infect(lambda, gamma, p0, isol_factor, times, loc, isol)
```

Arguments

nbeds	upper and lower bounds on number of beds
arrival	Poisson arrival rate of new patients
window	window of simulation
units	a named list with one entry per unit. Each entry is itself a list with the parameters of the Gamma-distribution for the duration of stay in the unit.
visits	list containing parameters of a negative binomial distribution for the number of visits per patient.
uperv	list containing parameters for a negative binomial distribution for the number of units visited per visit.
min_dur	minimum duration of stay in any unit
testing_freq	named numeric vector of unit-specific testing frequencies.
isolation	list containing parameters of the isolation model
infection	parameters of the infection model
alpha, beta	false positive and negative testing error rates
verbose	run-time information?
patient	patient name or number
t0, tf	initial and final times of patient itinerary
lambda	force of infection
gamma	recovery rate
p0	initial probability of infection
isol_factor	reduction in susceptibility due to isolation
times	times at which status is reported
loc	location of patient at each time
isol	isolation status

Details

Simulate hospital movement, testing, and isolation data.

Value

infection status vector

See Also

More on simulated data: fake_data

More on the independent infection model: independent

Examples

```
library(tidyverse)
library(lubridate)

## Examine the data:
fake_data

## Verify certain conditions hold:
stopifnot(
  `admission condition violation`=fake_data |>
    group_by(patient,visit) |> slice_head() |>
    filter(event!="admit") |> nrow()==0,
  `discharge condition violation`=fake_data |>
    group_by(patient,visit) |> slice_tail() |>
    filter(event!="discharge",event!="stop") |> nrow()==0,
  `unit violation`=fake_data |> filter(is.na(unit)) |> nrow()==0,
  `event violation`=fake_data |> filter(is.na(event)) |> nrow()==0
)

fake_data |>
  mutate(
    time=as.numeric(
      as.duration(
        interval(date,start="2000-01-01T00:00:00+0000")
      ),
      units="day"
    )
  ) -> fake_data

fake_data |>
  group_by(patient,visit) |>
  summarize(dur=max(time)-min(time)) |>
  ungroup() |>
  group_by(patient) |>
  summarize(dur=sum(dur)) |>
  ggplot(aes(x=log10(dur)))+
  geom_histogram(bins=20)+
  labs(title="total duration of hospitalization")+
  theme_bw()

fake_data |>
  group_by(patient,visit) |>
  summarize(dur=max(time)-min(time)) |>
  ungroup() |>
  ggplot(aes(x=log10(dur)))+
  geom_histogram(bins=40)+
  labs(title="duration of hospital visit")+
  theme_bw()

fake_data |>
  filter(
    event!="test",
```

```
    event!="isolate",
    event!="release",
    event!="stop"
  ) |>
  group_by(patient,visit) |>
  arrange(time) |>
  mutate(dur=lead(time)-time) |>
  ungroup() |>
  filter(unit!="out",!is.na(dur)) |>
  ggplot(aes(x=log10(dur),fill=unit,group=unit))+
  geom_histogram(aes(y=after_stat(density)),bins=40)+
  facet_grid(unit~.,scales="free_y")+
  labs(title="duration of stay by unit")+
  theme_bw()

fake_data |>
  group_by(patient) |>
  summarize(ntest=sum(event=="test")) |>
  ungroup() |>
  ggplot(aes(x=ntest))+
  geom_histogram(binwidth=1,center=0)+
  labs(title="number of tests per patient")+
  theme_bw()

fake_data |>
  arrange(time) |>
  mutate(
    dn=case_when(
      event=="admit"~1L,
      event=="discharge"~-1L,
      TRUE~0L
    ),
    occ=cumsum(dn)
  ) |>
  ggplot(aes(x=date,y=occ))+
  geom_step()+
  labs(title="hospital occupancy")+
  theme_bw()

fake_data |>
  arrange(time) |>
  select(date,test.result=result,isol,infected) |>
  pivot_longer(c(test.result,isol,infected)) |>
  filter(!is.na(value)) |>
  ggplot(aes(x=date,y=value,color=name))+
  geom_point()+
  geom_smooth()+
  guides(color="none")+
  labs(
    title="infection and isolation status, test results",
    y=""
  )+
  facet_grid(name~.)+
```

```
  theme_bw()

fake_data |>
  filter(event=="test") |>
  mutate(
    interval=cut(time,breaks=72,ordered=TRUE)
  ) |>
  select(interval,time,infected,isol,result) |>
  pivot_longer(c(infected,isol,result)) |>
  group_by(name,interval) |>
  summarize(
    time=mean(time),
    prev=mean(value),
    n=n()
  ) |>
  ungroup() |>
  ggplot(aes(x=time,y=prev,group=name,fill=name))+
  geom_col(position="dodge")+
  labs(title="infection, isolation, and detection through time")+
  theme_bw()+
  theme(axis.text.x=element_text(angle=90))

fake_data |>
  filter(event=="test") |>
  select(infected,result) |>
  count(infected,result) |>
  group_by(infected) |>
  mutate(prob=n/sum(n)) |>
  ungroup()
```

---

stobfun *Stateful objective functions*

Description

Convenience functions for constructing and working with stateful objective functions ('stobfun'-class objects).

Usage

```
stobfun(
  embed,
  params,
  est = character(0),
  log = character(0),
  logit = character(0),
  objfun,
  data
)
```

```
transf_fns(log = character(0), logit = character(0), est = character(0))

embedding(...)

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

Arguments

embed	embedding (see embedding).
params	vector of parameters
est	character: names of parameters to be estimated
log	character; names of parameters to log transform.
logit	character; names of parameters to logit transform.
objfun	underlying objective function
data	data
...	ignored.
object	'stobfun'-class stateful objective function

Details

objfun will be called as objfun(theta,data), where theta is the nested list constructed according to the given specifications and data is the data.

Value

transf_fns returns a list of two functions. The first is the transformation to the estimation scale; the second is its inverse.

embedding returns the embedding function corresponding to the given specification.

coef(f) returns the parameter vector corresponding to the last call of the stateful objective function f.

Construction and usage of stateful objective functions

A stateful objective function is an ordinary function that can be used as an objective function in an optimization problem. In particular, it can be passed to optimizers such as optim, subplex, or nloptr. It is stateful in the sense that it remembers the argument with which it was last called.

To construct a stateful objective function, call the constructor function for the model of interest. The constructor function requires that you pass a vector of model parameters: this gives the default parameter values. It also requires that you pass the data and the names of the parameters that you wish to estimate. The constructor will return an object of class 'stobfun'.

Having constructed a 'stobfun' stateful objective function, you can pass this to any suitable optimizer. Once the optimizer has returned, **it is important that you call the function one last time, at the parameters the optimizer has returned** (see examples). This ensures that the stored parameters are those at the (putative) optimum. You can retrieve these parameters via a call to coef.

See Also

More on stateful objective functions: independent, transmission

---

`transmission` *Transmission model*

Description

Model under which the force of infection in each unit is proportional to the prevalence of infection in that unit.

Usage

```
trans_homog_objfun(params, data, est = character(0))

trans_unit_spec_objfun(params, data, est = character(0))
```

Arguments

`params`	named vector of parameters
`data`	patient movement, isolation, and testing data
`est`	names of parameters to estimate

Details

`trans_homog_objfun` is a stateful objective function for the transmission model with a global b and gamma.

`trans_unit_spec_objfun` is a stateful objective function for the transmission model with unit-specific transmission rates, an out-of-hospital force of infection parameter, and recovery rates that can be different inside and outside of hospital.

See Also

More on stateful objective functions: independent, stobfun()

Examples

```
library(tidyverse)
library(hte)

set.seed(339613584)

fake_data |>
  ## filter out tests prior to day 250
  filter(
    event!="test" | time < 250,
    time < 1000
```

```
  ) |>
  select(-infected) |>
  arrange(patient,time) -> dat

trans_homog_objfun(
  params=c(
    bi=0.1,bu=0.1,gamma=0.01,p0=0.1,
    isol_factor=0.2,alpha=0.02,beta=0.1
  ),
  est=c("bu","bi"),
  data=dat
) -> f
f(log(c(0.4,0.02)))
coef(f)

## Not run:

optim(
  par=log(c(0.4,0.2)),
  fn=f,
  control=list(reltol=1e-2)
) -> out
f(out$par)
coef(f)


## End(Not run)

trans_unit_spec_objfun(
  params=c(
    bi.A=0.1,bi.B=0.1,bi.C=0.1,bi.D=0.1,bi.E=0.1,
    bu.A=0.1,bu.B=0.1,bu.C=0.1,bu.D=0.1,bu.E=0.1,
    gamma=0.01,p0=0.1,
    lambda.out=0.1,gamma.out=0.01,
    isol_factor=0.2,alpha=0.02,beta=0.1
  ),
  data=dat
) -> f
f()
coef(f)
```

`twostate` *twostate*

Description

Two-state Markov process with on and off rates

Usage

```
twostate(on, off, tf, t0 = 0)
```

Arguments

`on, off`	on and off rates
`t0, tf`	initial and final times

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