

# Package ‘EpiEstim’

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**Version** 2.2-5

**Title** Estimate Time Varying Reproduction Numbers from Epidemic Curves

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**Description** Tools to quantify transmissibility throughout an epidemic from the analysis of time series of incidence as described in Cori et al. (2013) <[doi:10.1093/aje/kwt133](https://doi.org/10.1093/aje/kwt133)> and Wallinga and Teunis (2004) <[doi:10.1093/aje/kwh255](https://doi.org/10.1093/aje/kwh255)>.

**URL** <https://github.com/mrc-ide/EpiEstim>

**BugReports** <https://github.com/mrc-ide/EpiEstim/issues>

**Depends** R (>= 2.10)

**Imports** coarseDataTools (>= 0.6-4), stats, graphics, reshape2, ggplot2, gridExtra, fitdistrplus, coda, incidence (>= 1.7.0), scales, grDevices

**Suggests** testthat, utils, vdiff, covr, knitr, rmarkdown

**License** GPL (>= 2)

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check\_cdt\_samples\_convergence  
*Checking convergence of an MCMC chain by using the Gelman-Rubin  
 algorithm*

---

## Description

check\_cdt\_samples\_convergence Checking convergence of an MCMC chain by using the Gelman-Rubin algorithm

**Usage**

```
check_cdt_samples_convergence(cdt_samples)
```

**Arguments**

cdt\_samples      the @sample slot of a cd.fit.mcmc S4 object (see package coarseDataTools)

**Details**

This function splits an MCMC chain in two halves and uses the Gelman-Rubin algorithm to assess convergence of the chain by comparing its two halves.

**Value**

TRUE if the Gelman Rubin test for convergence was successful, FALSE otherwise

**Author(s)**

Anne Cori

**See Also**

[estimate\\_R](#)

**Examples**

```
## Not run:
## Note the following examples use an MCMC routine
## to estimate the serial interval distribution from data,
## so they may take a few minutes to run

## load data on rotavirus
data("MockRotavirus")

## estimate the serial interval from data
SI_fit <- coarseDataTools::dic.fit.mcmc(dat = MockRotavirus$si_data,
                                       dist="G",
                                       init_pars=init_mcmc_params(MockRotavirus$si_data, "G"),
                                       burnin = 1000,
                                       n.samples = 5000)

## use check_cdt_samples_convergence to check convergence
converg_diag <- check_cdt_samples_convergence(SI_fit@samples)
converg_diag

## End(Not run)
```

---

coarse2estim                      *Link coarseDataTools and EpiEstim*

---

### Description

coarse2estim Transforms outputs of coarseDataTools::dic.fit.mcmc to right format for input into estimate\_R

### Usage

```
coarse2estim(x = NULL, dist = x@dist, samples = x@samples, thin = 10)
```

### Arguments

x	An object generated by function coarseDataTools::dic.fit.mcmc, containing posterior estimates of the serial interval distribution.
dist	The parametric distribution used when estimating the serial interval. # Should be one of "G" (Gamma), "W" (Weibull), "L" (Lognormal), "off1G" (Gamma shifted by 1), "off1W" (Weibull shifted by 1), or "off1L" (Lognormal shifted by 1). If not present, computed automatically from x.
samples	A dataframe containing the posterior samples of serial interval parameters corresponding to the parametric choice specified in dist. If not present, computed automatically from x.
thin	A positive integer corresponding to thinning parameter; of the posterior sample of serial interval distributions in x, only 1 in thin will be kept, the rest will be discarded.

### Value

A list with two elements: \* si\_sample: a matrix where each column gives one distribution of the serial interval to be explored, obtained from x by thinning the MCMC chain. \* si\_parametric\_distr: the parametric distribution used when estimating the serial interval stored in x.

### Author(s)

The Hackout3 Parameter Estimation team.

### See Also

[estimate\\_R](#)

**Examples**

```

## Not run:
## Note the following examples use an MCMC routine
## to estimate the serial interval distribution from data,
## so they may take a few minutes to run

## load data on rotavirus
data("MockRotavirus")

## estimate the serial interval from data
SI.fit <- coarseDataTools::dic.fit.mcmc(dat = MockRotavirus$si_data,
                                       dist = "G",
                                       init.pars = init_mcmc_params(MockRotavirus$si_data, "G"),
                                       burnin = 1000,
                                       n.samples = 5000)

## use coarse2estim to turn this in the right format for estimate_R
si_sample <- coarse2estim(SI.fit, thin = 10)$si_sample

## use estimate_R to estimate the reproduction number
## based on these estimates of the serial interval
R_si_from_sample <- estimate_R(MockRotavirus$incidence,
                               method="si_from_sample",
                               si_sample=si_sample,
                               config = make_config(list(n2 = 50)))

plot(R_si_from_sample)

## End(Not run)

```

---

DiscrSI

*Function to ensure compatibility with EpiEstim versions <2.0*


---

**Description**

Please only use for compatibility; Prefer the new `discr_si` function instead

**Usage**

```
DiscrSI(k, mu, sigma)
```

**Arguments**

k	see k in <code>discr_si</code>
mu	see mu in <code>discr_si</code>
sigma	see sigma in <code>discr_si</code>

---

discr_si	<i>Discretized Generation Time Distribution Assuming A Shifted Gamma Distribution</i>
----------	---

---

### Description

discr\_si computes the discrete distribution of the serial interval, assuming that the serial interval is shifted Gamma distributed, with shift 1.

### Usage

```
discr_si(k, mu, sigma)
```

### Arguments

k	Positive integer, or vector of positive integers for which the discrete distribution is desired.
mu	A positive real giving the mean of the Gamma distribution.
sigma	A non-negative real giving the standard deviation of the Gamma distribution.

### Details

Assuming that the serial interval is shifted Gamma distributed with mean  $\mu$ , standard deviation  $\sigma$  and shift 1, the discrete probability  $w_k$  that the serial interval is equal to  $k$  is:

$$w_k = kF_{\{\mu-1, \sigma\}}(k) + (k-2)F_{\{\mu-1, \sigma\}}(k-2) - 2(k-1)F_{\{\mu-1, \sigma\}}(k-1) + (\mu-1)(2F_{\{\mu-1 + \frac{\sigma^2}{\mu-1}, \sigma\sqrt{1 + \frac{\sigma^2}{\mu-1}}\}}(k-1) - F_{\{\mu-1 + \frac{\sigma^2}{\mu-1}\}})$$

where  $F_{\{\mu, \sigma\}}$  is the cumulative density function of a Gamma distribution with mean  $\mu$  and standard deviation  $\sigma$ .

### Value

Gives the discrete probability  $w_k$  that the serial interval is equal to  $k$ .

### Author(s)

Anne Cori <a.cor@imperial.ac.uk>

### References

Cori, A. et al. A new framework and software to estimate time-varying reproduction numbers during epidemics (AJE 2013).

### See Also

[overall\\_infectivity](#), [estimate\\_R](#)

## Examples

```
## Computing the discrete serial interval of influenza
mean_flu_si <- 2.6
sd_flu_si <- 1.5
dicrete_si_distr <- discr_si(seq(0, 20), mean_flu_si, sd_flu_si)
plot(seq(0, 20), dicrete_si_distr, type = "h",
      lwd = 10, lend = 1, xlab = "time (days)", ylab = "frequency")
title(main = "Discrete distribution of the serial interval of influenza")
```

---

EstimateR

*Function to ensure compatibility with EpiEstim versions <2.0*

---

## Description

Please only use for compatibility; Prefer the new estimate\_R function instead

## Usage

```
EstimateR(
  I,
  T.Start,
  T.End,
  method = c("NonParametricSI", "ParametricSI", "UncertainSI"),
  n1 = NULL,
  n2 = NULL,
  Mean.SI = NULL,
  Std.SI = NULL,
  Std.Mean.SI = NULL,
  Min.Mean.SI = NULL,
  Max.Mean.SI = NULL,
  Std.Std.SI = NULL,
  Min.Std.SI = NULL,
  Max.Std.SI = NULL,
  SI.Distr = NULL,
  Mean.Prior = 5,
  Std.Prior = 5,
  CV.Posterior = 0.3,
  plot = FALSE,
  leg.pos = "topright"
)
```

## Arguments

I	see incid in estimate_R
T.Start	see config\$t_start in estimate_R
T.End	see config\$t_end in estimate_R

method	see method in estimate_R (but EstimateR uses CamelCase where estimate_R uses snake_case for the method names)
n1	see n1 in estimate_R
n2	see n2 in estimate_R
Mean.SI	see config\$mean_si in estimate_R
Std.SI	see config\$std_si in estimate_R
Std.Mean.SI	see config\$std_mean_si in estimate_R
Min.Mean.SI	see config\$min_mean_si in estimate_R
Max.Mean.SI	see config\$max_mean_si in estimate_R
Std.Std.SI	see config\$std_std_si in estimate_R
Min.Std.SI	see config\$min_std_si in estimate_R
Max.Std.SI	see config\$max_std_si in estimate_R
SI.Distr	see config\$si_distr in estimate_R
Mean.Prior	see config\$mean_prior in estimate_R
Std.Prior	see config\$std_prior in estimate_R
CV.Posterior	see config\$cv_posterior in estimate_R
plot	Not used anymore, only there for compatibility
leg.pos	Not used anymore, only there for compatibility

---

estimate\_R

*Estimated Instantaneous Reproduction Number*

---

## Description

estimate\_R estimates the reproduction number of an epidemic, given the incidence time series and the serial interval distribution.

## Usage

```
estimate_R(
  incid,
  method = c("non_parametric_si", "parametric_si", "uncertain_si", "si_from_data",
    "si_from_sample"),
  si_data = NULL,
  si_sample = NULL,
  config = make_config(incid = incid, method = method)
)
```

**Arguments**

incid	<p>One of the following</p> <ul style="list-style-type: none"> <li>* A vector (or a dataframe with a single column) of non-negative integers containing the incidence time series</li> <li>* A dataframe of non-negative integers with either i) <code>incid\$I</code> containing the total incidence, or ii) two columns, so that <code>incid\$local</code> contains the incidence of cases due to local transmission and <code>incid\$imported</code> contains the incidence of imported cases (with <code>incid\$local + incid\$imported</code> the total incidence). If the dataframe contains a column <code>incid\$dates</code>, this is used for plotting. <code>incid\$dates</code> must contains only dates in a row.</li> <li>* An object of class <code>incidence</code></li> </ul> <p>Note that the cases from the first time step are always all assumed to be imported cases.</p>
method	One of "non_parametric_si", "parametric_si", "uncertain_si", "si_from_data" or "si_from_sample" (see details).
si_data	For method "si_from_data" ; the data on dates of symptoms of pairs of infector/infected individuals to be used to estimate the serial interval distribution (see details).
si_sample	For method "si_from_sample" ; a matrix where each column gives one distribution of the serial interval to be explored (see details).
config	An object of class <code>estimate_R_config</code> , as returned by function <code>make_config</code> .

**Details**

Analytical estimates of the reproduction number for an epidemic over predefined time windows can be obtained within a Bayesian framework, for a given discrete distribution of the serial interval (see references).

Several methods are available to specify the serial interval distribution.

In short there are five methods to specify the serial interval distribution (see help for function `make_config` for more detail on each method). In the first two methods, a unique serial interval distribution is considered, whereas in the last three, a range of serial interval distributions are integrated over:

- \* In method "non\_parametric\_si" the user specifies the discrete distribution of the serial interval
- \* In method "parametric\_si" the user specifies the mean and sd of the serial interval
- \* In method "uncertain\_si" the mean and sd of the serial interval are each drawn from truncated normal distributions, with parameters specified by the user
- \* In method "si\_from\_data", the serial interval distribution is directly estimated, using MCMC, from interval censored exposure data, with data provided by the user together with a choice of parametric distribution for the serial interval
- \* In method "si\_from\_sample", the user directly provides the sample of serial interval distribution to use for estimation of R. This can be a useful alternative to the previous method, where the MCMC estimation of the serial interval distribution could be run once, and the same estimated SI distribution then used in `estimate_R` in different contexts, e.g. with different time windows, hence avoiding to rerun the MCMC every time `estimate_R` is called.

**Value**

an object of class `estimate_R`, with components:

\* R: a dataframe containing: the times of start and end of each time window considered ; the posterior mean, std, and 0.025, 0.05, 0.25, 0.5, 0.75, 0.95, 0.975 quantiles of the reproduction number for each time window.

\* method: the method used to estimate R, one of "non\_parametric\_si", "parametric\_si", "uncertain\_si", "si\_from\_data" or "si\_from\_sample"

\* si\_distr: a vector or dataframe (depending on the method) containing the discrete serial interval distribution(s) used for estimation

\* SI.Moments: a vector or dataframe (depending on the method) containing the mean and std of the discrete serial interval distribution(s) used for estimation

\* I: the time series of total incidence

\* I\_local: the time series of incidence of local cases (so that  $I_{\text{local}} + I_{\text{imported}} = I$ )

\* I\_imported: the time series of incidence of imported cases (so that  $I_{\text{local}} + I_{\text{imported}} = I$ )

\* dates: a vector of dates corresponding to the incidence time series

\* MCMC\_converged (only for method si\_from\_data): a boolean showing whether the Gelman-Rubin MCMC convergence diagnostic was successful (TRUE) or not (FALSE)

### Author(s)

Anne Cori <a.cor@imperial.ac.uk>

### References

Cori, A. et al. A new framework and software to estimate time-varying reproduction numbers during epidemics (AJE 2013). Wallinga, J. and P. Teunis. Different epidemic curves for severe acute respiratory syndrome reveal similar impacts of control measures (AJE 2004). Reich, N.G. et al. Estimating incubation period distributions with coarse data (Statist. Med. 2009)

### See Also

[discr\\_si](#) [make\\_config](#)

### Examples

```
## load data on pandemic flu in a school in 2009
data("Flu2009")

## estimate the reproduction number (method "non_parametric_si")
## when not specifying t_start and t_end in config, they are set to estimate
## the reproduction number on sliding weekly windows
res <- estimate_R(incid = Flu2009$incidence,
                 method = "non_parametric_si",
                 config = make_config(list(si_distr = Flu2009$si_distr)))

plot(res)

## the second plot produced shows, at each each day,
## the estimate of the reproduction number over the 7-day window
## finishing on that day.
```

```

## to specify t_start and t_end in config, e.g. to have biweekly sliding
## windows
t_start <- seq(2, nrow(Flu2009$incidence)-13)
t_end <- t_start + 13
res <- estimate_R(incid = Flu2009$incidence,
                  method = "non_parametric_si",
                  config = make_config(list(
                    si_distr = Flu2009$si_distr,
                    t_start = t_start,
                    t_end = t_end)))

plot(res)

## the second plot produced shows, at each each day,
## the estimate of the reproduction number over the 14-day window
## finishing on that day.

## example with an incidence object

## create fake data
library(incidence)
data <- c(0,1,1,2,1,3,4,5,5,5,5,4,4,26,6,7,9)
location <- sample(c("local","imported"), length(data), replace=TRUE)
location[1] <- "imported" # forcing the first case to be imported

## get incidence per group (location)
incid <- incidence(data, groups = location)

## Estimate R with assumptions on serial interval
res <- estimate_R(incid, method = "parametric_si",
                  config = make_config(list(
                    mean_si = 2.6, std_si = 1.5)))

plot(res)
## the second plot produced shows, at each each day,
## the estimate of the reproduction number over the 7-day window
## finishing on that day.

## estimate the reproduction number (method "parametric_si")
res <- estimate_R(Flu2009$incidence, method = "parametric_si",
                  config = make_config(list(mean_si = 2.6, std_si = 1.5)))

plot(res)
## the second plot produced shows, at each each day,
## the estimate of the reproduction number over the 7-day window
## finishing on that day.

## estimate the reproduction number (method "uncertain_si")
res <- estimate_R(Flu2009$incidence, method = "uncertain_si",
                  config = make_config(list(
                    mean_si = 2.6, std_mean_si = 1,
                    min_mean_si = 1, max_mean_si = 4.2,
                    std_si = 1.5, std_std_si = 0.5,
                    min_std_si = 0.5, max_std_si = 2.5,
                    n1 = 100, n2 = 100)))

plot(res)

```



```

                                config = make_config(list(n2 = 50,
                                seed = overall_seed)))
plot(R_si_from_sample)

## check that R_si_from_sample is the same as R_si_from_data
## since they were generated using the same MCMC algorithm to generate the SI
## sample (either internally to EpiEstim or externally)
all(R_si_from_sample$R$`Mean(R)` == R_si_from_data$R$`Mean(R)` )

## End(Not run)

```

---

estimate_R_plots	<i>Wrapper for plot.estimate_R</i>
------------------	------------------------------------

---

## Description

This wrapper has been created so that several estimate\_R objects can be plotted at the same time.

## Usage

```
estimate_R_plots(..., legend = FALSE)
```

## Arguments

...	Arguments of <a href="#">plot.estimate_R</a> , but in addition, parameter x can be a objects of class estimate_R (obtained as outputs of functions <a href="#">estimate_R</a> or <a href="#">wallinga_teunis</a> . If x is a list, and what='R' or what='all', all estimates of R are plotted on a single graph. This will only work if all the estimate_R objects in the list were computed using the same config\$t_start and config\$t_end
legend	A boolean (TRUE by default) governing the presence / absence of legends on the plots

## Value

a plot (if what = "incid", "R", or "SI") or a [grob](#) object (if what = "all").

## Author(s)

Anne Cori, Zhian Kamvar

## See Also

[plot.estimate\\_R](#)

**Examples**

```

## load data on pandemic flu in a school in 2009
data("Flu2009")

#### COMPARE THE INSTANTANEOUS AND CASE REPRODUCTION NUMBERS ####

## estimate the instantaneous reproduction number
## (method "non_parametric_si")
R_instantaneous <- estimate_R(Flu2009$incidence,
  method = "non_parametric_si",
  config = list(t_start = seq(2, 26),
    t_end = seq(8, 32),
    si_distr = Flu2009$si_distr
  )
)

## estimate the case reproduction number
R_case <- wallinga_teunis(Flu2009$incidence,
  method = "non_parametric_si",
  config = list(t_start = seq(2, 26),
    t_end = seq(8, 32),
    si_distr = Flu2009$si_distr
  )
)

## visualise R estimates on the same plot
estimate_R_plots(list(R_instantaneous, R_case), what = "R",
  options_R = list(col = c("blue", "red")), legend = TRUE)

#### COMPARE THE INSTANTANEOUS R ON SLIDING WEEKLY OR BIWEEKLY WINDOWS ####

R_weekly <- estimate_R(Flu2009$incidence,
  method = "non_parametric_si",
  config = list(t_start = seq(9, 26),
    t_end = seq(15, 32),
    si_distr = Flu2009$si_distr
  )
)

R_biweekly <- estimate_R(Flu2009$incidence,
  method = "non_parametric_si",
  config = list(t_start = seq(2, 19),
    t_end = seq(15, 32),
    si_distr = Flu2009$si_distr
  )
)

## visualise R estimates on the same plot
estimate_R_plots(list(R_weekly, R_biweekly), what = "R",
  options_R = list(col = c("blue", "red")), legend = TRUE)

```

---

Flu1918

*Data on the 1918 H1N1 influenza pandemic in Baltimore.*

---

## Description

This data set gives:

1. the daily incidence of onset of disease in Baltimore during the 1918 H1N1 influenza pandemic (see source and references),
2. the discrete daily distribution of the serial interval for influenza, assuming a shifted Gamma distribution with mean 2.6 days, standard deviation 1.5 days and shift 1 day (see references).

## Format

A list of two elements:

- **incidence**: a vector containing 92 days of observation,
- **si\_distr**: a vector containing a set of 12 probabilities.

## Source

Frost W. and E. Sydenstricker (1919) Influenza in Maryland: preliminary statistics of certain localities. Public Health Rep.(34): 491-504.

## References

- Cauchemez S. et al. (2011) Role of social networks in shaping disease transmission during a community outbreak of 2009 H1N1 pandemic influenza. Proc Natl Acad Sci U S A 108(7), 2825-2830.
- Ferguson N.M. et al. (2005) Strategies for containing an emerging influenza pandemic in Southeast Asia. Nature 437(7056), 209-214.
- Fraser C. et al. (2011) Influenza Transmission in Households During the 1918 Pandemic. Am J Epidemiol 174(5): 505-514.
- Frost W. and E. Sydenstricker (1919) Influenza in Maryland: preliminary statistics of certain localities. Public Health Rep.(34): 491-504.
- Vynnycky E. et al. (2007) Estimates of the reproduction numbers of Spanish influenza using morbidity data. Int J Epidemiol 36(4): 881-889.
- White L.F. and M. Pagano (2008) Transmissibility of the influenza virus in the 1918 pandemic. PLoS One 3(1): e1498.

## Examples

```
## load data on pandemic flu in Baltimore in 1918
data("Flu1918")

## estimate the reproduction number (method "non_parametric_si")
res <- estimate_R(Flu1918$incidence,
```

```

        method = "non_parametric_si",
        config = make_config(list(si_distr = Flu1918$si_distr))
plot(res)
## the second plot produced shows, at each each day,
## the estimate of the reproduction number
## over the 7-day window finishing on that day.

```

Flu2009

*Data on the 2009 H1N1 influenza pandemic in a school in Pennsylvania.*

### Description

This data set gives:

1. the daily incidence of onset of acute respiratory illness (ARI, defined as at least two symptoms among fever, cough, sore throat, and runny nose) among children in a school in Pennsylvania during the 2009 H1N1 influenza pandemic (see source and references),
2. the discrete daily distribution of the serial interval for influenza, assuming a shifted Gamma distribution with mean 2.6 days, standard deviation 1.5 days and shift 1 day (see references).
3. interval-censored serial interval data from the 2009 outbreak of H1N1 influenza in San Antonio, Texas, USA (see references).

### Format

A list of three elements:

- **incidence:** a dataframe with 32 lines containing dates in first column, and daily incidence in second column (Cauchemez et al., 2011),
- **si\_distr:** a vector containing a set of 12 probabilities (Ferguson et al, 2005),
- **si\_data:** a dataframe with 16 lines giving serial interval patient data collected in a household study in San Antonio, Texas throughout the 2009 H1N1 outbreak (Morgan et al., 2010).

### Source

Cauchemez S. et al. (2011) Role of social networks in shaping disease transmission during a community outbreak of 2009 H1N1 pandemic influenza. *Proc Natl Acad Sci U S A* 108(7), 2825-2830.

Morgan O.W. et al. (2010) Household transmission of pandemic (H1N1) 2009, San Antonio, Texas, USA, April-May 2009. *Emerg Infect Dis* 16: 631-637.

### References

Cauchemez S. et al. (2011) Role of social networks in shaping disease transmission during a community outbreak of 2009 H1N1 pandemic influenza. *Proc Natl Acad Sci U S A* 108(7), 2825-2830.

Ferguson N.M. et al. (2005) Strategies for containing an emerging influenza pandemic in Southeast Asia. *Nature* 437(7056), 209-214.

**Examples**

```

## load data on pandemic flu in a school in 2009
data("Flu2009")

## estimate the reproduction number (method "non_parametric_si")
res <- estimate_R(Flu2009$incidence, method="non_parametric_si",
                 config = make_config(list(si_distr = Flu2009$si_distr)))
plot(res)
## the second plot produced shows, at each each day,
## the estimate of the reproduction number
## over the 7-day window finishing on that day.

## Not run:
## Note the following examples use an MCMC routine
## to estimate the serial interval distribution from data,
## so they may take a few minutes to run

## estimate the reproduction number (method "si_from_data")
res <- estimate_R(Flu2009$incidence, method="si_from_data",
                 si_data = Flu2009$si_data,
                 config = make_config(list(mcmc_control = make_mcmc_control(list(
                                     burnin = 1000,
                                     thin = 10, seed = 1)),
                                     n1 = 1000, n2 = 50,
                                     si_parametric_distr = "G"))))
plot(res)
## the second plot produced shows, at each each day,
## the estimate of the reproduction number
## over the 7-day window finishing on that day.

## End(Not run)

```

---

flu_2009_NYC_school	<i>Data on the 2009 H1N1 influenza pandemic in a school in New York city</i>
---------------------	--

---

**Description**

This data set gives:

1. the daily incidence of self-reported and laboratory-confirmed cases of influenza among children in a school in New York city during the 2009 H1N1 influenza pandemic (see source and references),
2. interval-censored serial interval data from the 2009 outbreak of H1N1 influenza in a New York city school (see references).

## Format

A list of two elements:

- **incidence**: a dataframe with 14 lines containing dates in first column, and daily incidence in second column ,
- **si\_data**: a dataframe containing data on the generation time for 16 pairs of infector/infected individuals (see references and see argument `si_data` of function `estimate_R` for details on columns)

## Source

Lessler J. et al. (2009) Outbreak of 2009 pandemic influenza A (H1N1) at a New York City school. *New Eng J Med* 361: 2628-2636.

## References

Lessler J. et al. (2009) Outbreak of 2009 pandemic influenza A (H1N1) at a New York City school. *New Eng J Med* 361: 2628-2636.

## Examples

```
## Not run:
## Note the following examples use an MCMC routine
## to estimate the serial interval distribution from data,
## so they may take a few minutes to run

## load data on pandemic flu in a New York school in 2009
data("flu_2009_NYC_school")

## estimate the reproduction number (method "si_from_data")
res <- estimate_R(flu_2009_NYC_school$incidence, method="si_from_data",
  si_data = flu_2009_NYC_school$si_data,
  config = make_config(list(
    t_start = seq(2, 8),
    t_end = seq(8, 14),
    si_parametric_distr = "G",
    mcmc_control = make_mcmc_control(list(burnin = 1000,
      thin = 10, seed = 1)),
    n1 = 1000, n2 = 50))
  )
plot(res)
## the second plot produced shows, at each each day,
## the estimate of the reproduction number
## over the 7-day window finishing on that day.

## End(Not run)
```

---

init_mcmc_params	init_mcmc_params <i>Finds clever starting points for the MCMC to be used to estimate the serial interval, e.g. when using option si_from_data in estimate_R</i>
------------------	---

---

### Description

init\_mcmc\_params Finds values of the serial interval distribution parameters, used to initialise the MCMC estimation of the serial interval distribution. Initial values are computed based on the observed mean and standard deviation of the sample from which the parameters are to be estimated.

### Usage

```
init_mcmc_params(si_data, dist = c("G", "W", "L", "off1G", "off1W", "off1L"))
```

### Arguments

si_data	the data on dates of symptoms of pairs of infector/infected individuals to be used to estimate the serial interval distribution. This should be a dataframe with 5 columns: * EL: the lower bound of the symptom onset date of the infector (given as an integer) * ER: the upper bound of the symptom onset date of the infector (given as an integer). Should be such that $ER \geq EL$ * SL: the lower bound of the symptom onset date of the infected individual (given as an integer) * SR: the upper bound of the symptom onset date of the infected individual (given as an integer). Should be such that $SR \geq SL$ * type (optional): can have entries 0, 1, or 2, corresponding to doubly interval-censored, single interval-censored or exact observations, respectively, see Reich et al. Statist. Med. 2009. If not specified, this will be automatically computed from the dates
dist	the parametric distribution to use for the serial interval. Should be one of "G" (Gamma), "W" (Weibull), "L" (Lognormal), "off1G" (Gamma shifted by 1), "off1W" (Weibull shifted by 1), or "off1L" (Lognormal shifted by 1).

### Value

A vector containing the initial values for the two parameters of the distribution of the serial interval. These are the shape and scale for all but the lognormal distribution, for which it is the meanlog and sdlog.

### Author(s)

Anne Cori

### See Also

[estimate\\_R](#)

## Examples

```
## Not run:
## Note the following examples use an MCMC routine
## to estimate the serial interval distribution from data,
## so they may take a few minutes to run

## load data on rotavirus
data("MockRotavirus")

## get clever initial values for shape and scale of a Gamma distribution
## fitted to the the data MockRotavirus$si_data
clever_init_param <- init_mcmc_params(MockRotavirus$si_data, "G")

## estimate the serial interval from data using a clever starting point for
## the MCMC chain
SI_fit_clever <- coarseDataTools::dic.fit.mcmc(dat = MockRotavirus$si_data,
      dist = "G",
      init.pars = clever_init_param,
      burnin = 1000,
      n.samples = 5000)

## estimate the serial interval from data using a random starting point for
## the MCMC chain
SI_fit_naive <- coarseDataTools::dic.fit.mcmc(dat = MockRotavirus$si_data,
      dist = "G",
      burnin = 1000,
      n.samples = 5000)

## use check_cdt_samples_convergence to check convergence in both situations
converg_diag_clever <- check_cdt_samples_convergence(SI_fit_clever@samples)
converg_diag_naive <- check_cdt_samples_convergence(SI_fit_naive@samples)
converg_diag_clever
converg_diag_naive

## End(Not run)
```

---

make\_config

*Set and check parameter settings of estimate\_R*

---

## Description

This function defines settings for estimate\_R. It takes a list of named items as input, set defaults where arguments are missing, and return a list of settings.

**Usage**

```

make_config(
  ...,
  incid = NULL,
  method = c("non_parametric_si", "parametric_si", "uncertain_si", "si_from_data",
            "si_from_sample")
)

```

**Arguments**

... Acceptable arguments for ... are:

- \* `t_start`: Vector of positive integers giving the starting times of each window over which the reproduction number will be estimated. These must be in ascending order, and so that for all  $i$ ,  $t\_start[i] \leq t\_end[i]$ .  $t\_start[1]$  should be strictly after the first day with non null incidence.
- \* `t_end`: Vector of positive integers giving the ending times of each window over which the reproduction number will be estimated. These must be in ascending order, and so that for all  $i$ ,  $t\_start[i] \leq t\_end[i]$ .
- \* `n1`: For method "uncertain\_si" and "si\_from\_data"; positive integer giving the size of the sample of SI distributions to be drawn (see details).
- \* `n2`: For methods "uncertain\_si", "si\_from\_data" and "si\_from\_sample"; positive integer giving the size of the sample drawn from the posterior distribution of  $R$  for each serial interval distribution considered (see details).
- \* `mean_si`: For method "parametric\_si" and "uncertain\_si"; positive real giving the mean serial interval (method "parametric\_si") or the average mean serial interval (method "uncertain\_si", see details).
- \* `std_si`: For method "parametric\_si" and "uncertain\_si"; non negative real giving the standard deviation of the serial interval (method "parametric\_si") or the average standard deviation of the serial interval (method "uncertain\_si", see details).
- \* `std_mean_si`: For method "uncertain\_si"; standard deviation of the distribution from which mean serial intervals are drawn (see details).
- \* `min_mean_si`: For method "uncertain\_si"; lower bound of the distribution from which mean serial intervals are drawn (see details).
- \* `max_mean_si`: For method "uncertain\_si"; upper bound of the distribution from which mean serial intervals are drawn (see details).
- \* `std_std_si`: For method "uncertain\_si"; standard deviation of the distribution from which standard deviations of the serial interval are drawn (see details).
- \* `min_std_si`: For method "uncertain\_si"; lower bound of the distribution from which standard deviations of the serial interval are drawn (see details).
- \* `max_std_si`: For method "uncertain\_si"; upper bound of the distribution from which standard deviations of the serial interval are drawn (see details).
- \* `si_distr`: For method "non\_parametric\_si"; vector of probabilities giving the discrete distribution of the serial interval, starting with `si_distr[1]` (probability that the serial interval is zero), which should be zero.
- \* `si_parametric_distr`: For method "si\_from\_data"; the parametric distribution to use when estimating the serial interval from data on dates of symptoms

of pairs of infector/infected individuals (see details). Should be one of "G" (Gamma), "W" (Weibull), "L" (Lognormal), "off1G" (Gamma shifted by 1), "off1W" (Weibull shifted by 1), or "off1L" (Lognormal shifted by 1).

\* `mcmc_control`: An object of class `estimate_R_mcmc_control`, as returned by function `make_mcmc_control`.

\* `seed`: An optional integer used as the seed for the random number generator at the start of the function (then potentially reset within the MCMC for method `si_from_data`); useful to get reproducible results.

\* `mean_prior`: A positive number giving the mean of the common prior distribution for all reproduction numbers (see details).

\* `std_prior`: A positive number giving the standard deviation of the common prior distribution for all reproduction numbers (see details).

\* `cv_posterior`: A positive number giving the aimed posterior coefficient of variation (see details).

<code>incid</code>	As in function <code>estimate_R</code> .
<code>method</code>	As in function <code>estimate_R</code> .

## Details

Analytical estimates of the reproduction number for an epidemic over predefined time windows can be obtained using function `estimate_R`, for a given discrete distribution of the serial interval. `make_config` allows to generate a configuration specifying the way the estimation will be performed.

The more incident cases are observed over a time window, the smallest the posterior coefficient of variation (CV, ratio of standard deviation over mean) of the reproduction number. An aimed CV can be specified in the argument `cv_posterior` (default is 0.3), and a warning will be produced if the incidence within one of the time windows considered is too low to get this CV.

The methods vary in the way the serial interval distribution is specified.

In short there are five methods to specify the serial interval distribution (see below for details on each method). In the first two methods, a unique serial interval distribution is considered, whereas in the last three, a range of serial interval distributions are integrated over:

\* In method `"non_parametric_si"` the user specifies the discrete distribution of the serial interval  
 \* In method `"parametric_si"` the user specifies the mean and sd of the serial interval  
 \* In method `"uncertain_si"` the mean and sd of the serial interval are each drawn from truncated normal distributions, with parameters specified by the user  
 \* In method `"si_from_data"`, the serial interval distribution is directly estimated, using MCMC, from interval censored exposure data, with data provided by the user together with a choice of parametric distribution for the serial interval  
 \* In method `"si_from_sample"`, the user directly provides the sample of serial interval distribution to use for estimation of R. This can be a useful alternative to the previous method, where the MCMC estimation of the serial interval distribution could be run once, and the same estimated SI distribution then used in `estimate_R` in different contexts, e.g. with different time windows, hence avoiding to rerun the MCMC everytime `estimate_R` is called.

————— method `"non_parametric_si"` —————

The discrete distribution of the serial interval is directly specified in the argument `si_distr`.

————— method `"parametric_si"` —————

The mean and standard deviation of the continuous distribution of the serial interval are given in the arguments `mean_si` and `std_si`. The discrete distribution of the serial interval is derived automatically using `discr_si`.

————— method "uncertain\_si" —————

method="uncertain\_si" allows accounting for uncertainty on the serial interval distribution as described in Cori et al. AJE 2013. We allow the mean  $\mu$  and standard deviation  $\sigma$  of the serial interval to vary according to truncated normal distributions. We sample  $n_1$  pairs of mean and standard deviations,  $(\mu^{(1)}, \sigma^{(1)}), \dots, (\mu^{(n_2)}, \sigma^{(n_2)})$ , by first sampling the mean  $\mu^{(k)}$  from its truncated normal distribution (with mean `mean_si`, standard deviation `std_mean_si`, minimum `min_mean_si` and maximum `max_mean_si`), and then sampling the standard deviation  $\sigma^{(k)}$  from its truncated normal distribution (with mean `std_si`, standard deviation `std_std_si`, minimum `min_std_si` and maximum `max_std_si`), but imposing that  $\sigma^{(k)} < \mu^{(k)}$ . This constraint ensures that the Gamma probability density function of the serial interval is null at  $t = 0$ . Warnings are produced when the truncated normal distributions are not symmetric around the mean. For each pair  $(\mu^{(k)}, \sigma^{(k)})$ , we then draw a sample of size  $n_2$  in the posterior distribution of the reproduction number over each time window, conditionally on this serial interval distribution. After pooling, a sample of size  $n_1 \times n_2$  of the joint posterior distribution of the reproduction number over each time window is obtained. The posterior mean, standard deviation, and 0.025, 0.05, 0.25, 0.5, 0.75, 0.95, 0.975 quantiles of the reproduction number for each time window are obtained from this sample.

————— method "si\_from\_data" —————

method="si\_from\_data" allows accounting for uncertainty on the serial interval distribution. Unlike method "uncertain\_si", where we arbitrarily vary the mean and std of the SI in truncated normal distributions, here, the scope of serial interval distributions considered is directly informed by data on the (potentially censored) dates of symptoms of pairs of infector/infected individuals. This data, specified in argument `si_data`, should be a dataframe with 5 columns: \* EL: the lower bound of the symptom onset date of the infector (given as an integer) \* ER: the upper bound of the symptom onset date of the infector (given as an integer). Should be such that  $ER \geq EL$  \* SL: the lower bound of the symptom onset date of the infected individual (given as an integer) \* SR: the upper bound of the symptom onset date of the infected individual (given as an integer). Should be such that  $SR \geq SL$  \* type (optional): can have entries 0, 1, or 2, corresponding to doubly interval-censored, single interval-censored or exact observations, respectively, see Reich et al. Statist. Med. 2009. If not specified, this will be automatically computed from the dates

Assuming a given parametric distribution for the serial interval distribution (specified in `si_parametric_distr`), the posterior distribution of the serial interval is estimated directly from these data using MCMC methods implemented in the package `coarsedatatools`. The argument `mcmc_control` is a list of characteristics which control the MCMC. The MCMC is run for a total number of iterations of `mcmc_control$burnin + n1*mcmc_control$thin`; but the output is only recorded after the burnin, and only 1 in every `mcmc_control$thin` iterations, so that the posterior sample size is  $n_1$ . For each element in the posterior sample of serial interval distribution, we then draw a sample of size  $n_2$  in the posterior distribution of the reproduction number over each time window, conditionally on this serial interval distribution. After pooling, a sample of size  $n_1 \times n_2$  of the joint posterior distribution of the reproduction number over each time window is obtained. The posterior mean, standard deviation, and 0.025, 0.05, 0.25, 0.5, 0.75, 0.95, 0.975 quantiles of the reproduction number for each time window are obtained from this sample.

————— method "si\_from\_sample" —————

method="si\_from\_sample" also allows accounting for uncertainty on the serial interval distribution. Unlike methods "uncertain\_si" and "si\_from\_data", the user directly provides (in argument

si\_sample) a sample of serial interval distribution to be explored.

## Value

An object of class `estimate_R_config` with components `t_start`, `t_end`, `n1`, `n2`, `mean_si`, `std_si`, `std_mean_si`, `min_mean_si`, `max_mean_si`, `std_std_si`, `min_std_si`, `max_std_si`, `si_distr`, `si_parametric_distr`, `mcmc_control`, `seed`, `mean_prior`, `std_prior`, `cv_posterior`, which can be used as an argument of function `estimate_R`.

## Examples

```
## Not run:
## Note the following examples use an MCMC routine
## to estimate the serial interval distribution from data,
## so they may take a few minutes to run

## load data on rotavirus
data("MockRotavirus")

## estimate the reproduction number (method "si_from_data")
## we are not specifying the time windows, so by defaults this will estimate
## R on sliding weekly windows
incid <- MockRotavirus$incidence
method <- "si_from_data"
config <- make_config(incid = incid,
                      method = method,
                      list(si_parametric_distr = "G",
                           mcmc_control = make_mcmc_control(burnin = 1000,
                                                             thin = 10, seed = 1),
                           n1 = 500,
                           n2 = 50,
                           seed = 2))

R_si_from_data <- estimate_R(incid,
                             method = method,
                             si_data = MockRotavirus$si_data,
                             config = config)

plot(R_si_from_data)

## you can also create the config straight within the estimate_R call,
## in that case incid and method are automatically used from the estimate_R
## arguments:
R_si_from_data <- estimate_R(incid,
                             method = method,
                             si_data = MockRotavirus$si_data,
                             config = make_config(
                               list(si_parametric_distr = "G",
                                    mcmc_control = make_mcmc_control(burnin = 1000,
                                                                      thin = 10, seed = 1),
                                    n1 = 500,
                                    n2 = 50,
                                    seed = 2)))
```

```
plot(R_si_from_data)

## End(Not run)
```

---

make_mcmc_control	<i>make_mcmc_control</i> Creates a list of mcmc control parameters to be used in <code>config\$mcmc_control</code> , where <code>config</code> is an argument of the <code>estimate_R</code> function. This is used to configure the MCMC chain used to estimate the serial interval within <code>estimate_R</code> (with method <code>"si_from_data"</code> ).
-------------------	---

---

### Description

`make_mcmc_control` Creates a list of mcmc control parameters to be used in `config$mcmc_control`, where `config` is an argument of the `estimate_R` function. This is used to configure the MCMC chain used to estimate the serial interval within `estimate_R` (with method `"si_from_data"`).

### Usage

```
make_mcmc_control(
  burnin = 3000,
  thin = 10,
  seed = as.integer(Sys.time()),
  init_pars = NULL
)
```

### Arguments

burnin	A positive integer giving the burnin used in the MCMC when estimating the serial interval distribution.
thin	A positive integer corresponding to thinning parameter; the MCMC will be run for <code>burnin+n1*thin</code> iterations; 1 in <code>thin</code> iterations will be recorded, after the burnin phase, so the posterior sample size is <code>n1</code> .
seed	An integer used as the seed for the random number generator at the start of the MCMC estimation; useful to get reproducible results.
init_pars	vector of size 2 corresponding to the initial values of parameters to use for the SI distribution. This is the shape and scale for all but the lognormal distribution, for which it is the meanlog and sdlog.

### Details

The argument `si_data`, should be a dataframe with 5 columns: \* EL: the lower bound of the symptom onset date of the infector (given as an integer) \* ER: the upper bound of the symptom onset date of the infector (given as an integer). Should be such that  $ER \geq EL$  \* SL: the lower bound of the symptom onset date of the infected individual (given as an integer) \* SR: the upper bound of the symptom onset date of the infected individual (given as an integer). Should be such that  $SR \geq SL$  \* type (optional): can have entries 0, 1, or 2, corresponding to doubly interval-censored,

single interval-censored or exact observations, respectively, see Reich et al. *Statist. Med.* 2009. If not specified, this will be automatically computed from the dates

Assuming a given parametric distribution for the serial interval distribution (specified in `si_parametric_distr`), the posterior distribution of the serial interval is estimated directly from these data using MCMC methods implemented in the package

### Value

An object of class `estimate_R_mcmc_control` with components `burnin`, `thin`, `seed`, `init_pars`. This can be used as an argument of function `make_config`.

### Examples

```
## Not run:
## Note the following examples use an MCMC routine
## to estimate the serial interval distribution from data,
## so they may take a few minutes to run

## load data on rotavirus
data("MockRotavirus")

## estimate the reproduction number (method "si_from_data")
mcmc_seed <- 1
burnin <- 1000
thin <- 10
mcmc_control <- make_mcmc_control(burnin = burnin, thin = thin,
                                seed = mcmc_seed)

incid <- MockRotavirus$incidence
method <- "si_from_data"
overall_seed <- 2
config <- make_config(incid = incid,
                      method = method,
                      si_parametric_distr = "G",
                      mcmc_control = mcmc_control,
                      n1 = 500
                      n2 = 50,
                      seed = overall_seed)

R_si_from_data <- estimate_R(incid,
                             method = method,
                             si_data = MockRotavirus$si_data,
                             config = config)

## End(Not run)
```

## Description

This data set gives:

1. the daily incidence of onset of symptoms in Hallegoch (Germany) during the 1861 measles epidemic (see source and references),
2. the discrete daily distribution of the serial interval for measles, assuming a shifted Gamma distribution with mean 14.9 days, standard deviation 3.9 days and shift 1 day (see references).

## Format

A list of two elements:

- **incidence:** a vector containing 48 days of observation,
- **si\_distr:** a vector containing a set of 38 probabilities.

## Source

Groendyke C. et al. (2011) Bayesian Inference for Contact Networks Given Epidemic Data. Scandinavian Journal of Statistics 38(3): 600-616.

## References

Groendyke C. et al. (2011) Bayesian Inference for Contact Networks Given Epidemic Data. Scandinavian Journal of Statistics 38(3): 600-616.

## Examples

```
## load data on measles in Hallegoch in 1861
data("Measles1861")

## estimate the reproduction number (method "non_parametric_si")
res <- estimate_R(Measles1861$incidence, method="non_parametric_si",
  config = make_config(list(
    t_start = seq(17, 42),
    t_end = seq(23, 48),
    si_distr = Measles1861$si_distr)))

plot(res)
## the second plot produced shows, at each each day,
## the estimate of the reproduction number
## over the 7-day window finishing on that day.
```



```

std_si = mers_2014_15$si$std_si,
t_start = 2:(nrow(mers_2014_15$incidence)-8*7),
t_end = (2:(nrow(mers_2014_15$incidence)-8*7)) + 8*7))

plot(bimonthly_R, legend = FALSE, add_imported_cases = TRUE,
      options_I = list(col = c("local" = "black",
                              "imported" = "red"),
                      interval = 7, # show weekly incidence
                      ylab = "Weekly incidence"),
      options_R = list(ylab = "Bimonthly R"))
# The first plot shows the weekly incidence,
# with imported cases shown in red and local cases in black

```

---

MockRotavirus

*Mock data on a rotavirus epidemic.*


---

## Description

This data set gives:

1. the daily incidence of onset of symptoms in a mock outbreak of rotavirus,
2. mock observations of symptom onset dates for 19 pairs of infector/infected individuals.

## Format

A list of two elements:

- **incidence:** a vector containing 53 days of observation,
- **si\_distr:** a dataframe containing a set of 19 observations; each observation corresponds to a pair of infector/infected individuals. EL and ER columns contain the lower and upper bounds of the dates of symptoms onset in the infectors. SL and SR columns contain the lower and upper bounds of the dates of symptoms onset in the infected individuals. The type column has entries 0, 1, or 2, corresponding to doubly interval-censored, single interval-censored or exact observations, respectively, see Reich et al. Statist. Med. 2009

## Examples

```

## Not run:
## Note the following example uses an MCMC routine
## to estimate the serial interval distribution from data,
## so may take a few minutes to run

## load data
data("MockRotavirus")

## estimate the reproduction number (method "si_from_data")
res <- estimate_R(MockRotavirus$incidence,
                  method = "si_from_data",

```

```

si_data = MockRotavirus$si_data,
config = make_config(list(
  si_parametric_distr = "G",
  mcmc_control = make_mcmc_control(list(burnin = 3000, thin = 10)),
  n1 = 500, n2 = 50)))
plot(res)
## the second plot produced shows, at each each day,
## the estimate of the reproduction number
## over the 7-day window finishing on that day.

## End(Not run)

```

---

OverallInfectivity      *Function to ensure compatibility with EpiEstim versions <2.0*

---

### Description

Please only use for compatibility; Prefer the new overall\_infectivity function instead

### Usage

```
OverallInfectivity(I, SI.Distr)
```

### Arguments

I	see incid in overall_infectivity
SI.Distr	see si_distr in overall_infectivity

---

overall\_infectivity      *Overall Infectivity Due To Previously Infected Individuals*

---

### Description

overall\_infectivity computes the overall infectivity due to previously infected individuals.

### Usage

```
overall_infectivity(incid, si_distr)
```

### Arguments

incid	One of the following: * A vector (or a dataframe with a single column) of non-negative integers containing an incidence time series * A dataframe of non-negative integers with two columns, so that incid\$local contains the incidence of cases due to local transmission and incid\$imported contains the incidence of imported cases (with incid\$local + incid\$imported the total incidence). Note that the cases from the first time step are always all assumed to be imported cases.
si_distr	Vector of probabilities giving the discrete distribution of the serial interval.

**Details**

The overall infectivity  $\lambda_t$  at time step  $t$  is equal to the sum of the previously infected individuals (given by the incidence vector  $I$ , with  $I = \text{incid}\$local + \text{incid}\$imported$  if  $I$  is a matrix), weighed by their infectivity at time  $t$  (given by the discrete serial interval distribution  $w_k$ ). In mathematical terms:

$$\lambda_t = \sum_{k=1}^{t-1} I_{t-k} w_k$$

**Value**

A vector which contains the overall infectivity  $\lambda_t$  at each time step

**Author(s)**

Anne Cori <a.corii@imperial.ac.uk>

**References**

Cori, A. et al. A new framework and software to estimate time-varying reproduction numbers during epidemics (AJE 2013).

**See Also**

[discr\\_si](#), [estimate\\_R](#)

**Examples**

```
## load data on pandemic flu in a school in 2009
data("Flu2009")

## compute overall infectivity
lambda <- overall_infectivity(Flu2009$incidence, Flu2009$si_distr)
par(mfrow=c(2,1))
plot(Flu2009$incidence, type = "s", xlab = "time (days)", ylab = "incidence")
title(main = "Epidemic curve")
plot(lambda, type = "s", xlab = "time (days)", ylab = "Infectivity")
title(main = "Overall infectivity")
```

---

plot.estimate\_R

*Plot outputs of estimate\_r*

---

**Description**

The plot method of estimate\_r objects can be used to visualise three types of information. The first one shows the epidemic curve. The second one shows the posterior mean and 95% credible interval of the reproduction number. The estimate for a time window is plotted at the end of the time window. The third plot shows the discrete distribution(s) of the serial interval.

**Usage**

```
## S3 method for class 'estimate_R'
plot(
  x,
  what = c("all", "incid", "R", "SI"),
  add_imported_cases = FALSE,
  options_I = list(col = palette(), transp = 0.7, xlim = NULL, ylim = NULL, interval =
    1L, xlab = "Time", ylab = "Incidence"),
  options_R = list(col = palette(), transp = 0.2, xlim = NULL, ylim = NULL, xlab =
    "Time", ylab = "R"),
  options_SI = list(prob_min = 0.001, col = "black", transp = 0.25, xlim = NULL, ylim =
    NULL, xlab = "Time", ylab = "Frequency"),
  legend = TRUE,
  ...
)
```

**Arguments**

x	The output of function <a href="#">estimate_R</a> or function <a href="#">wallinga_teunis</a> . To plot simultaneous outputs on the same plot use <a href="#">estimate_R_plots</a> function
what	A string specifying what to plot, namely the incidence time series (what='incid'), the estimated reproduction number (what='R'), the serial interval distribution (what='SI'), or all three (what='all').
add_imported_cases	A boolean to specify whether, on the incidence time series plot, to add the incidence of imported cases.
options_I	For what = "incid" or "all". A list of graphical options: * col: A color or vector of colors used for plotting incid. By default uses the default R colors. * transp: A numeric value between 0 and 1 used to monitor transparency of the bars plotted. Defaults to 0.7. * xlim: A parameter similar to that in par, to monitor the limits of the horizontal axis * ylim: A parameter similar to that in par, to monitor the limits of the vertical axis * interval: An integer or character indicating the (fixed) size of the time interval used for plotting the incidence; defaults to 1 day. * xlab, ylab: Labels for the axes of the incidence plot
options_R	For what = "R" or "all". A list of graphical options: * col: A color or vector of colors used for plotting R. By default uses the default R colors. * transp: A numeric value between 0 and 1 used to monitor transparency of the 95%CrI. Defaults to 0.2. * xlim: A parameter similar to that in par, to monitor the limits of the horizontal axis * ylim: A parameter similar to that in par, to monitor the limits of the vertical axis * xlab, ylab: Labels for the axes of the R plot
options_SI	For what = "SI" or "all". A list of graphical options: * prob_min: A numeric value between 0 and 1. The SI distributions explored are only shown from time 0 up to the time t so that each distribution explored has probability < prob_min to be on any time step after t. Defaults to 0.001. * col: A color or vector of colors used for plotting the SI. Defaults to black. * transp: A numeric value between 0 and 1 used to monitor transparency of the lines. Defaults to 0.25 * xlim: A parameter similar to that in par, to monitor the limits of the horizontal axis *

	ylim: A parameter similar to that in par, to monitor the limits of the vertical axis * xlab, ylab: Labels for the axes of the serial interval distribution plot
legend	A boolean (TRUE by default) governing the presence / absence of legends on the plots
...	further arguments passed to other methods (currently unused).

**Value**

a plot (if what = "incid", "R", or "SI") or a [grob](#) object (if what = "all").

**Author(s)**

Rolina van Gaalen <rolina.van.gaaalen@rivm.nl> and Anne Cori <a.cori@imperial.ac.uk>;  
S3 method by Thibaut Jombart

**See Also**

[estimate\\_R](#), [wallinga\\_teunis](#) and [estimate\\_R\\_plots](#)

**Examples**

```
## load data on pandemic flu in a school in 2009
data("Flu2009")

## estimate the instantaneous reproduction number
## (method "non_parametric_si")
R_i <- estimate_R(Flu2009$incidence,
                 method = "non_parametric_si",
                 config = list(t_start = seq(2, 26),
                              t_end = seq(8, 32),
                              si_distr = Flu2009$si_distr
                             )
                )

## visualise results
plot(R_i, legend = FALSE)

## estimate the instantaneous reproduction number
## (method "non_parametric_si")
R_c <- wallinga_teunis(Flu2009$incidence,
                     method = "non_parametric_si",
                     config = list(t_start = seq(2, 26),
                                    t_end = seq(8, 32),
                                    si_distr = Flu2009$si_distr
                                   )
                    )

## produce plot of the incidence
## (with, on top of total incidence, the incidence of imported cases),
## estimated instantaneous and case reproduction numbers
## and serial interval distribution used
```

```

p_I <- plot(R_i, "incid", add_imported_cases=TRUE) # plots the incidence
p_SI <- plot(R_i, "SI") # plots the serial interval distribution
p_Ri <- plot(R_i, "R",
            options_R = list(ylim = c(0, 4)))
            # plots the estimated instantaneous reproduction number
p_Rc <- plot(R_c, "R",
            options_R = list(ylim = c(0, 4)))
            # plots the estimated case reproduction number
gridExtra::grid.arrange(p_I, p_SI, p_Ri, p_Rc, ncol = 2)

```

---

sample\_posterior\_R     *sample from the posterior R distribution*

---

### Description

sample from the posterior R distribution

### Usage

```
sample_posterior_R(R, n = 1000, window = 1L)
```

### Arguments

R	an estimate_R object from the estimate_r function function.
n	an integer specifying the number of samples to be taken from the gamma distribution.
window	an integer (or sequence of integers) specifying the window(s) from which to estimate R. Defaults to the first window. If multiple windows are specified, the resulting samples will be drawn from several distributions.

### Value

n values of R from the posterior R distribution

### Author(s)

Anne Cori

### Examples

```

## load data on pandemic flu in a school in 2009
data("Flu2009")

## estimate the reproduction number (method "non_parametric_si")
## when not specifying t_start and t_end in config, they are set to estimate
## the reproduction number on sliding weekly windows
res <- estimate_R(incid = Flu2009$incidence,

```

```

method = "non_parametric_si",
config = make_config(list(si_distr = Flu2009$si_distr)))

## Sample R from the first weekly window
win <- 1L
R_median <- res$R$`Median(R)`[win]
R_CrI <- c(res$R$`Quantile.0.025(R)`[win], res$R$`Quantile.0.975(R)`[win])

set.seed(2019-06-06) # fixing the random seed for reproducibility
R_sample <- sample_posterior_R(res, n = 1000, window = win)
hist(R_sample, col = "grey", main = "R sampled from the first weekly window")
abline(v = R_median, col = "red") # show the median estimated R
abline(v = R_CrI, col = "red", lty = 2) # show the 95%CrI of R

```

SARS2003

*Data on the 2003 SARS epidemic in Hong Kong.***Description**

This data set gives:

1. the daily incidence of onset of symptoms in Hong Kong during the 2003 severe acute respiratory syndrome (SARS) epidemic (see source and references),
2. the discrete daily distribution of the serial interval for SARS, assuming a shifted Gamma distribution with mean 8.4 days, standard deviation 3.8 days and shift 1 day (see references).

**Format**

A list of two elements:

- **incidence:** a vector containing 107 days of observation,
- **si\_distr:** a vector containing a set of 25 probabilities.

**Source**

Cori A. et al. (2009) Temporal variability and social heterogeneity in disease transmission: the case of SARS in Hong Kong. *PLoS Comput Biol* 5(8) : e1000471.

**References**

Cori A. et al. (2009) Temporal variability and social heterogeneity in disease transmission: the case of SARS in Hong Kong. *PLoS Comput Biol* 5(8): e1000471.

Lipsitch M. et al. (2003) Transmission dynamics and control of severe acute respiratory syndrome. *Science* 300(5627): 1966-1970.

**Examples**

```
## load data on SARS in Hong Kong in 2003
data("SARS2003")

## estimate the reproduction number (method "non_parametric_si")
res <- estimate_R(SARS2003$incidence, method="non_parametric_si",
  config = make_config(list(
    t_start = seq(14, 101),
    t_end = seq(20, 107),
    si_distr = SARS2003$si_distr)))

plot(res)
## the second plot produced shows, at each each day,
## the estimate of the reproduction number
## over the 7-day window finishing on that day.
```

---

Smallpox1972

*Data on the 1972 smallpox epidemic in Kosovo*


---

**Description**

This data set gives:

1. the daily incidence of onset of symptoms in Kosovo during the 1972 smallpox epidemic (see source and references),
2. the discrete daily distribution of the serial interval for smallpox, assuming a shifted Gamma distribution with mean 22.4 days, standard deviation 6.1 days and shift 1 day (see references).

**Format**

A list of two elements:

- **incidence:** a vector containing 57 days of observation,
- **si\_distr:** a vector containing a set of 46 probabilities.

**Source**

Fenner F. et al. (1988) Smallpox and its Eradication. Geneva, World Health Organization.

**References**

- Fenner F. et al. (1988) Smallpox and its Eradication. Geneva, World Health Organization.
- Gani R. and S. Leach (2001) Transmission potential of smallpox in contemporary populations. *Nature* 414(6865): 748-751.
- Riley S. and N. M. Ferguson (2006) Smallpox transmission and control: spatial dynamics in Great Britain. *Proc Natl Acad Sci U S A* 103(33): 12637-12642.

## Examples

```
## load data on smallpox in Kosovo in 1972
data("Smallpox1972")

## estimate the reproduction number (method "non_parametric_si")
res <- estimate_R(Smallpox1972$incidence, method="non_parametric_si",
  config = make_config(list(
    t_start = seq(27, 51),
    t_end = seq(33, 57),
    si_distr = Smallpox1972$si_distr)))

plot(res)
## the second plot produced shows, at each each day,
## the estimate of the reproduction number
## over the 7-day window finishing on that day.
```

---

wallinga_teunis	<i>Estimation of the case reproduction number using the Wallinga and Teunis method</i>
-----------------	--

---

## Description

wallinga\_teunis estimates the case reproduction number of an epidemic, given the incidence time series and the serial interval distribution.

## Usage

```
wallinga_teunis(
  incid,
  method = c("non_parametric_si", "parametric_si"),
  config
)
```

## Arguments

incid	One of the following * Vector (or a dataframe with a column named 'incid') of non-negative integers containing an incidence time series. If the dataframe contains a column incid\$dates, this is used for plotting. incid\$dates must contain only dates in a row. * An object of class [incidence]
method	the method used to estimate R, one of "non_parametric_si", "parametric_si", "uncertain_si", "si_from_data" or "si_from_sample"
config	a list with the following elements: * t_start: Vector of positive integers giving the starting times of each window over which the reproduction number will be estimated. These must be in ascending order, and so that for all i, t_start[i] <= t_end[i]. t_start[1] should be strictly after the first day with non null incidence. * t_end: Vector of positive integers giving the ending times of each window over which the reproduction number will be estimated. These must

be in ascending order, and so that for all  $i$ ,  $t\_start[i] \leq t\_end[i]$ . \* method: One of "non\_parametric\_si" or "parametric\_si" (see details). \* mean\_si: For method "parametric\_si" ; positive real giving the mean serial interval. \* std\_si: For method "parametric\_si" ; non negative real giving the standard deviation of the serial interval. \* si\_distr: For method "non\_parametric\_si" ; vector of probabilities giving the discrete distribution of the serial interval, starting with  $si\_distr[1]$  (probability that the serial interval is zero), which should be zero. \* n\_sim: A positive integer giving the number of simulated epidemic trees used for computation of the confidence intervals of the case reproduction number (see details).

### Details

Estimates of the case reproduction number for an epidemic over predefined time windows can be obtained, for a given discrete distribution of the serial interval, as proposed by Wallinga and Teunis (AJE, 2004). Confidence intervals are obtained by simulating a number (`config$n_sim`) of possible transmission trees (only done if `config$n_sim > 0`).

The methods vary in the way the serial interval distribution is specified.

————— method "non\_parametric\_si" —————

The discrete distribution of the serial interval is directly specified in the argument `config$si_distr`.

————— method "parametric\_si" —————

The mean and standard deviation of the continuous distribution of the serial interval are given in the arguments `config$mean_si` and `config$std_si`. The discrete distribution of the serial interval is derived automatically using [discr\\_si](#).

### Value

a list with components: \* R: a dataframe containing: the times of start and end of each time window considered ; the estimated mean, std, and 0.025 and 0.975 quantiles of the reproduction number for each time window. \* si\_distr: a vector containing the discrete serial interval distribution used for estimation \* SIMoments: a vector containing the mean and std of the discrete serial interval distribution(s) used for estimation \* I: the time series of total incidence \* I\_local: the time series of incidence of local cases (so that  $I\_local + I\_imported = I$ ) \* I\_imported: the time series of incidence of imported cases (so that  $I\_local + I\_imported = I$ ) \* dates: a vector of dates corresponding to the incidence time series

### Author(s)

Anne Cori <a.corri@imperial.ac.uk>

### References

Cori, A. et al. A new framework and software to estimate time-varying reproduction numbers during epidemics (AJE 2013). Wallinga, J. and P. Teunis. Different epidemic curves for severe acute respiratory syndrome reveal similar impacts of control measures (AJE 2004).

### See Also

[discr\\_si](#), [estimate\\_R](#)

**Examples**

```

## load data on pandemic flu in a school in 2009
data("Flu2009")

## estimate the case reproduction number (method "non_parametric_si")
res <- wallinga_teunis(Flu2009$incidence,
  method="non_parametric_si",
  config = list(t_start = seq(2, 26), t_end = seq(8, 32),
    si_distr = Flu2009$si_distr,
    n_sim = 100))
plot(res)
## the second plot produced shows, at each each day,
## the estimate of the case reproduction number over the 7-day window
## finishing on that day.

## estimate the case reproduction number (method "parametric_si")
res <- wallinga_teunis(Flu2009$incidence, method="parametric_si",
  config = list(t_start = seq(2, 26), t_end = seq(8, 32),
    mean_si = 2.6, std_si = 1.5,
    n_sim = 100))
plot(res)
## the second plot produced shows, at each each day,
## the estimate of the case reproduction number over the 7-day window
## finishing on that day.

```

---

WT

---

*Function to ensure compatibility with EpiEstim versions <2.0*


---

**Description**

Please only use for compatibility; Prefer the new wallinga\_teunis function instead

**Usage**

```

WT(
  I,
  T.Start,
  T.End,
  method = c("NonParametricSI", "ParametricSI"),
  Mean.SI = NULL,
  Std.SI = NULL,
  SI.Distr = NULL,
  nSim = 10,
  plot = FALSE,
  leg.pos = "topright"
)

```

**Arguments**

I	see incid in wallinga_teunis
T.Start	see config\$t_start in wallinga_teunis
T.End	see config\$t_end in wallinga_teunis
method	see method in wallinga_teunis (but WT uses CamelCase where wallinga_teunis uses snake_case for the method names)
Mean.SI	see config\$mean_si in wallinga_teunis
Std.SI	see config\$std_si in wallinga_teunis
SI.Distr	see config\$si_distr in wallinga_teunis
nSim	see config\$n_sim in wallinga_teunis
plot	Not used anymore, only there for compatibility
leg.pos	Not used anymore, only there for compatibility

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