Evaluate {EpiEstim} on five epidemic outbreaks

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2020-08-23

(Cori et al. 2013) used the following five examples to demonstrate {EpiEstim} in thier paper. As the first step of {EpiEstim} evalution, we reproduced Figure1 and generated a table summarize the comparison of the current version and the result resported in Cori et al.

```
library(EpiEstim)
library(ggplot2)

data(Measles1861)
data(Flu1918)
data(Smallpox1972)
data(SARS2003)
data(Flu2009)
```

Each data containis at least two varriables, a serise of number of cases (i.e. incidence) and a distirbution of serial intervals (i.e. si_distr) as in Flu 2009.

```
head(Flu2009$incidence)
```

```
##        dates I
## 1 2009-04-27 1
## 2 2009-04-28 1
## 3 2009-04-29 0
## 4 2009-04-30 2
## 5 2009-05-01 5
## 6 2009-05-02 3
```

```
Flu2009$si_distr
```

```
##  [1] 0.000 0.233 0.359 0.198 0.103 0.053 0.027 0.014 0.007 0.003 0.002 0.001
```

Several options are available for different estimators for a distribution of serial intervals in {EpiEstim}: 1) `nonparametric_si' with the supplied density weights (si_distr), 2)`parametric_si' with options in `contig', such as mean_si, std_si, or 3) learning a distribution of serial intervals from data or samples using mcmc through`make_contig' function. Details of each option can be learned from ("EpiEstim: The R-Epi Project" 2020), ("EpiEstim: Github Repository" 2020), (Anne Cori 2020).

Reproducing Figure 1

With the provided si_distr, we can obtain Rt estimates non-parametrically with a default of 7 day sliding window as follows:

```
Rt_measles1861 <- estimate_R(incid = Measles1861$incidence,
                         method = "non_parametric_si",
                         config = make_config(list(si_distr = Measles1861$si_distr)))

round(head(Rt_measles1861$R[,c(1:4, 5, 8, 11)], 15), 1)
```

```
##    t_start t_end Mean(R) Std(R) Quantile.0.025(R) Median(R) Quantile.0.975(R)
## 1        2     8      NA     NA                NA        NA                NA
## 2        3     9      NA     NA                NA        NA                NA
## 3        4    10      NA     NA                NA        NA                NA
## 4        5    11      NA     NA                NA        NA                NA
## 5        6    12      NA     NA                NA        NA                NA
## 6        7    13      NA     NA                NA        NA                NA
## 7        8    14      NA     NA                NA        NA                NA
## 8        9    15     8.2    2.9               3.5       7.8              14.7
## 9       10    16     5.1    2.1               1.9       4.8               9.9
## 10      11    17     5.1    1.9               2.0       4.8               9.5
## 11      12    18     4.5    1.7               1.8       4.2               8.3
## 12      13    19     4.5    1.6               2.0       4.3               8.2
## 13      14    20     3.6    1.3               1.4       3.4               6.6
## 14      15    21     3.2    1.2               1.3       3.0               5.9
## 15      16    22     3.6    1.2               1.7       3.5               6.4
```

```
Rt_flu1918 <- estimate_R(incid = Flu1918$incidence,
                         method = "non_parametric_si",
                         config = make_config(list(si_distr = Flu1918$si_distr)))

round(head(Rt_flu1918$R[,c(1:4, 5, 8, 11)]),1)
```

```
##   t_start t_end Mean(R) Std(R) Quantile.0.025(R) Median(R) Quantile.0.975(R)
## 1       2     8     1.4    0.2               1.0       1.4               1.9
## 2       3     9     1.2    0.2               0.9       1.2               1.6
## 3       4    10     1.4    0.2               1.0       1.4               1.7
## 4       5    11     1.0    0.2               0.7       1.0               1.3
## 5       6    12     1.3    0.2               1.0       1.3               1.6
## 6       7    13     1.2    0.2               0.9       1.2               1.6
```

```
Rt_Smallpox1972 <- estimate_R(incid = Smallpox1972$incidence,
                              method = "non_parametric_si",
                              config = make_config(list(si_distr = Smallpox1972$si_distr)))

round(head(Rt_Smallpox1972$R[,c(1:4, 5, 8, 11)], 10),1)
```

```
##    t_start t_end Mean(R) Std(R) Quantile.0.025(R) Median(R) Quantile.0.975(R)
## 1        2     8      NA     NA                NA        NA                NA
## 2        3     9      NA     NA                NA        NA                NA
## 3        4    10      NA     NA                NA        NA                NA
## 4        5    11      NA     NA                NA        NA                NA
## 5        6    12      NA     NA                NA        NA                NA
## 6        7    13      NA     NA                NA        NA                NA
## 7        8    14      NA     NA                NA        NA                NA
## 8        9    15      NA     NA                NA        NA                NA
## 9       10    16      NA     NA                NA        NA                NA
## 10      11    17      NA     NA                NA        NA                NA
```

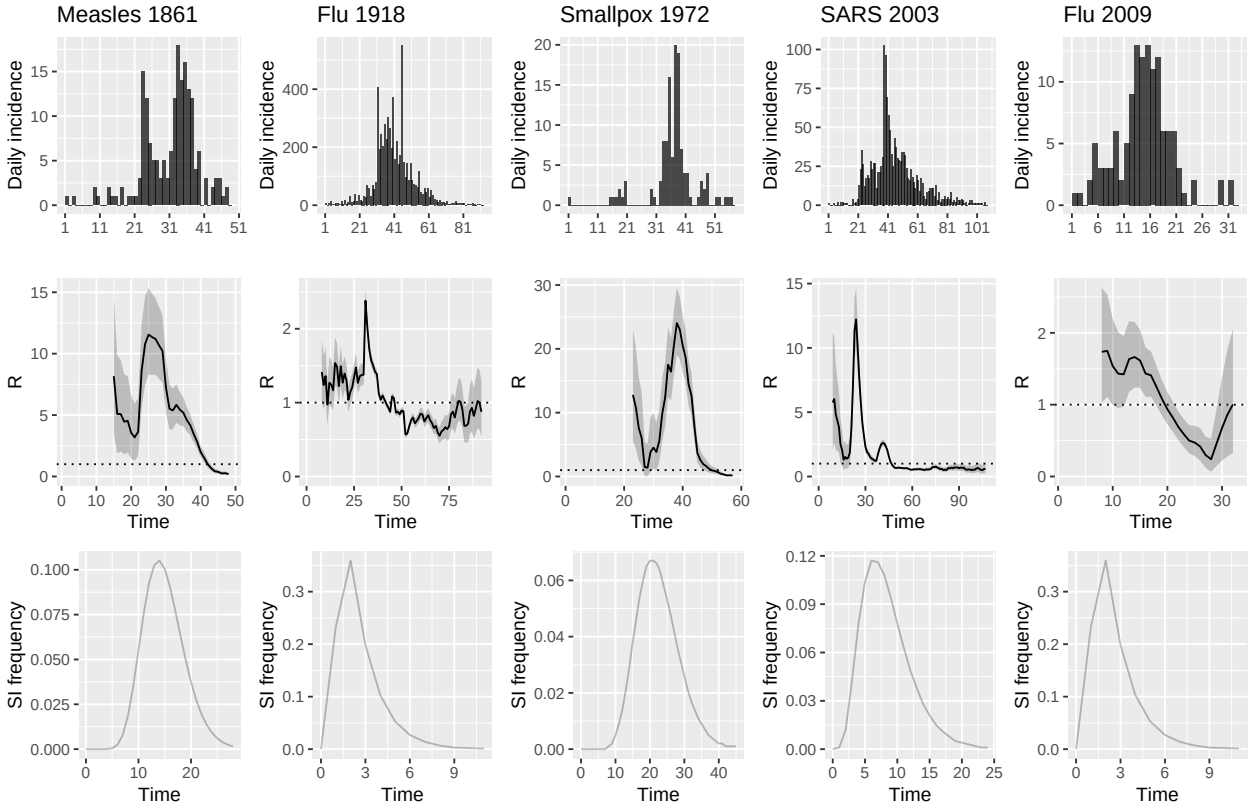
```
Rt_sars2003 <- estimate_R(incid = SARS2003$incidence,
                          method = "non_parametric_si",
                          config = make_config(list(si_distr = SARS2003$si_distr)))

round(head(Rt_sars2003$R[,c(1:4, 5, 8, 11)]), 1)
```

```
##   t_start t_end Mean(R) Std(R) Quantile.0.025(R) Median(R) Quantile.0.975(R)
```

```
## 1       2     8      NA     NA                 NA        NA                 NA
## 2       3     9     5.8    2.4                2.1       5.4               11.2
## 3       4    10     6.0    2.1                2.6       5.8               10.9
## 4       5    11     4.8    1.7                2.1       4.6                8.7
## 5       6    12     4.3    1.4                2.0       4.2                7.6
## 6       7    13     3.9    1.2                1.9       3.7                6.6
```

```
Rt_flu2009 <- estimate_R(incid = Flu2009$incidence$I,
                         method = "non_parametric_si",
                         config = make_config(list(si_distr = Flu2009$si_distr)))
round(head(Rt_flu2009$R[,c(1:4, 5, 8, 11)]), 1)
```

```
##   t_start t_end Mean(R) Std(R) Quantile.0.025(R) Median(R) Quantile.0.975(R)
## 1       2     8     1.7    0.4                1.0       1.7               2.6
## 2       3     9     1.7    0.4                1.1       1.7               2.5
## 3       4    10     1.5    0.3                1.0       1.5               2.2
## 4       5    11     1.4    0.3                1.0       1.4               2.0
## 5       6    12     1.4    0.3                1.0       1.4               2.0
## 6       7    13     1.6    0.3                1.2       1.6               2.2
```



Comparison

Over the years, some features of {EpiEstim} have been updated thus minor differences are observed. Characteristics of each case curve and differences in the reproduced numbers are summarized as follows.

Outbreak	Cori et al (2013)	Reproduced
`Measles 1861` increased Rt in w3-4	initial : 4.3 (95 % CI: 2-8.2) mid w3: 3.0 (95 % CI: 1.3–5.9)	4.2 (95 Q: 1.8-8.3) at d=18 2.8 (95 Q: 2.2-3.4) at d=39

Outbreak	Cori et al (2013)	Reproduced
due to the high	mid w4: 11.5 (95 % CI: 8.3–15.3)	no second peak after d=29 last d Rt>10
transsibility	w7: below 1	0.99 (95 Q: 0.7-1.3) at d=42
`Flu 1918`	end w2 : 1.4 (95 % CI: 1.0–1.9)	1.4 (95 Q: 1.0-1.9) at d =8, 10
2 days of extremely	mid w5: 2.4 (95 % CI: 2.2–2.6)	2.2 (95 Q: 2.4-2.6) at d = 31
high incidence at d=31, 45	early w7: below 1	1.0 (95 Q: 0.9 - 1.0) at d = 42 0.9 (95 Q: 0.8-0.9) at d = 47
`Smallpox 1972`	early w4: 3.4 (95% CI: 0.8–9.3)	3.4 (95 Q: 0.8-9.3) at d = 29
a long induction	mid w6: 23.9 (95% CI: 19.0–29.5)	23.9 (95 Q: 19.1-29.5 at d = 38
period (4 wk)	early w8: below 1	0.9 (95 Q: 0.5-1.6) at d = 50
`SARS 2003`	mid w3: 12.2 (95% CI: 10.0–14.7)	12.2 (95 Q: 10.0-14.7) at d = 24
2 peaks	end w6: 2.6 (95% CI: 2.4–2.9)	2.4 (95 Q: 2.6-2.9) at d = 41, 42
	w7: below 1	0.9 (95 Q: 0.8-1.0) at d = 47
`Flu 2009`	early w2: 1.7 (95% CI: 1.0–2.6)	1.7 (95 Q: 1.0–2.6) at d = 8
a constant rate	end w2: 1.7 (95% CI: 1.2–2.2)	1.7 (95 Q: 1.2–2.2) at d = 14
	w4: 0.2 (95% CI: 0.1–0.5)	0.2 (95 Q: 0.1–0.5) at d = 28
	w5: 0.9 (95% CI: 0.3–2.0)	0.9 (95 Q: 0.3–2.1) at d = 32

- Reproduced estimates are sample quantiles, median (quanteil at 0.025 - quantile at 0.975).
- 95Q indicates 95 sample quantile intervals. Cori et al. used a term of 95% CI but it seems they referring to the quantile intervals.
- d indicates t_end in R_t result.

Conclusion

With fixed serial interval weights, the estimates are consistent in the reproducible studies.

A true challenge in a COVID 19 study is to obtain an sensible estimate for this distribution.

Reference

Anne Cori, Neil M. Ferguson, Simon Cauchemez. 2020. *EpiEstim: Estimate Time Varying Reproduction Numbers from Epidemic Curves*. https://cran.r-project.org/web/packages/EpiEstim/index.html.

Cori, Anne, Neil M Ferguson, Christophe Fraser, and Simon Cauchemez. 2013. "A New Framework and Software to Estimate Time-Varying Reproduction Numbers During Epidemics." *American Journal of Epidemiology* 178 (9). Oxford University Press: 1505–12.

"EpiEstim: Github Repository." 2020. https://github.com/mrc-ide/EpiEstim.

"EpiEstim: The R-Epi Project." 2020. https://sites.google.com/site/therepiproject/r-pac/epiestim.