SEIAR model with ascertainment rate estimate

RNDr. Lenka Přibylová, Ph.D. and RNDr. Veronika Hajnová, Ph.D.
pribylova@math.muni.cz

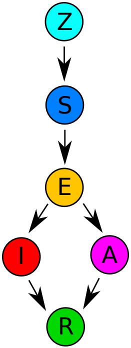
Department of Mathematics and Statistics, Faculty of Science, Masaryk University, Brno, Czech Rep.

25. 5. 2021

Mechanistic SEIAR model with A compartment of absent unobserved infected estimated from hospital data with incorporated mobility data dependence; optimized to the compartment of all exposed (unobserved included)

$$
\begin{aligned}
\dot{Z} &= -\varepsilon Z/N, \\
\dot{S} &= -\tfrac{\beta}{N-Z} S(I+A) + \varepsilon Z/N, \\
\dot{E} &= \tfrac{\beta}{N-Z} S(I+A) - \gamma E, \\
\dot{I} &= \gamma p E - \mu_1 I, \\
\dot{A} &= \gamma(1-p)E - \mu_2 A, \\
\dot{Q} &= \mu_1 I - \nu Q, \\
\dot{R} &= \nu Q,
\end{aligned}
$$

Z not affected population size
S susceptibles
E exposed
I detected infectious
A undetected infectious
Q izolated infectious
R removed detected
N population size
p ascertainment rate
$\varepsilon, \beta, \gamma, \mu_1, \mu_2, \nu$ parameters



- optimization to the size of the affected clusters that imply the size of the exposed compartment

- optimization to the size of the affected clusters that imply the size of the exposed compartment
- we use estimates of latent or infectious periods from the literature

- optimization to the size of the affected clusters that imply the size of the exposed compartment
- we use estimates of latent or infectious periods from the literature
- computable periods as isolation time or time to hospitalization or death, and a 14-day moving average ascertainment rate are estimated from dataset of Institute of Health Information and Statistics

- optimization to the size of the affected clusters that imply the size of the exposed compartment
- we use estimates of latent or infectious periods from the literature
- computable periods as isolation time or time to hospitalization or death, and a 14-day moving average ascertainment rate are estimated from dataset of Institute of Health Information and Statistics
- primary usage – estimate of the health care facilities shortage

Assumptions:

- We can estimate the ratio of the detected/reported cases.

Assumptions:

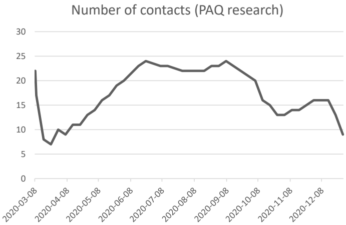
- We can estimate the ratio of the detected/reported cases.
  The basic principle for estimation of the moving ascertainment rate estimate is based on the Bayes rule.

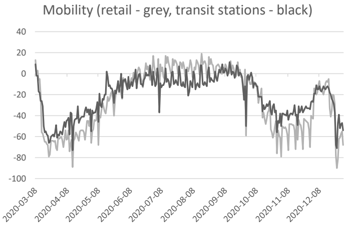
Assumptions:

- We can estimate the ratio of the detected/reported cases.
- Mobility correlates with average number of contacts.

Assumptions:

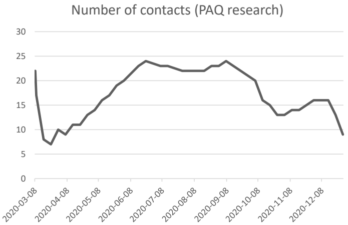
- We can estimate the ratio of the detected/reported cases.
- Mobility correlates with average number of contacts.

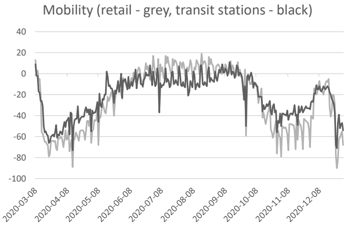




Assumptions:

- We can estimate the ratio of the detected/reported cases.
- Mobility correlates with average number of contacts.





- Other effects (interventions, seasonality, compliance, . . .) may be included into affected clusters estimate.

Ascertainment rate estimate

$$p = P(Det) = \frac{P(Det|H)P(H)}{P(H|Det)}$$

- $P(Det|H)$ – the probability that a person hospitalized with COVID-19 was previously detected

Ascertainment rate estimate

$$p = P(Det) = \frac{P(Det|H)P(H)}{P(H|Det)}$$

- $P(Det|H)$ – the probability that a person hospitalized with COVID-19 was previously detected
- $P(H|Det)$ – the probability that if an individual was detected, he or she will be hospitalized

Ascertainment rate estimate

$$p = P(Det) = \frac{P(Det|H)P(H)}{P(H|Det)}$$

- $P(Det|H)$ – the probability that a person hospitalized with COVID-19 was previously detected
- $P(H|Det)$ – the probability that if an individual was detected, he or she will be hospitalized
- $P(H)$ – the probability that SARS-CoV-2 positive individual is/was/will be hospitalized

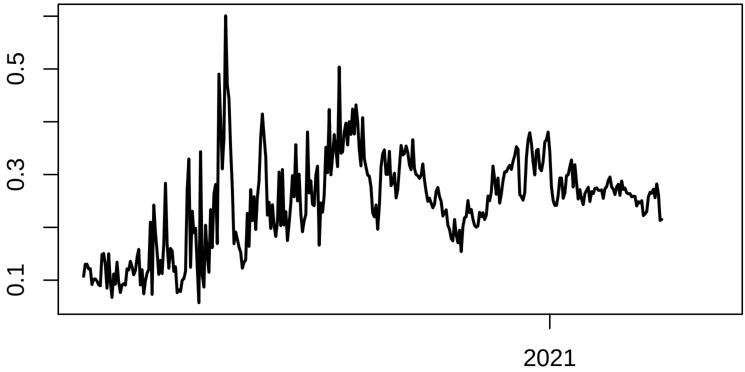
Hospitalization probability age structure dependence

Age structure in the Czech Republic attained 20% share of the over 65 year-old population. Patients hospitalized with COVID-19 over the age of 65 had a long-term ratio of around 3/4 during the autumn 2020, so a rough estimate of probability $P(H_{65+})$ of hospitalization with COVID-19 for a person over 65 is around twelve times higher than probability $P(H_{65-})$ of hospitalization with COVID-19 for a person under 65.

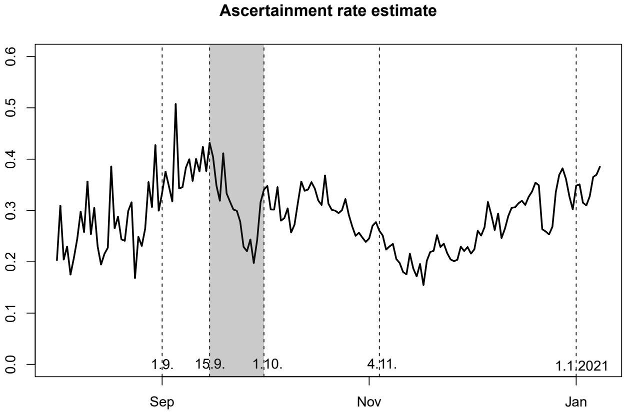
$$P(H) = p^{+}_{65-}P(H_{65-}) + p^{+}_{65+}P(H_{65+}) =$$
$$= \left(1 + 11\frac{p^{+}_{65+}}{p^{+}_{65-}}\right)P(H_{65-}),$$

where p^{+}_{65+} and p^{+}_{65-} are 7-day moving averages of the senior and non-senior population ratio in the reported positive cases.

Ascertainment rate estimate



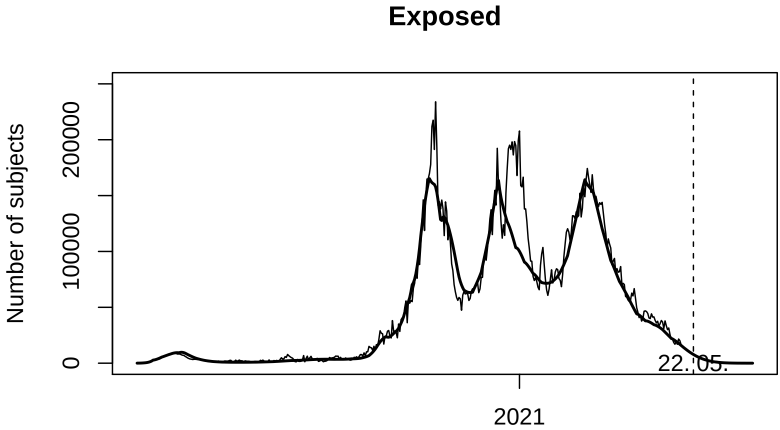
Early warning – fail of tracing



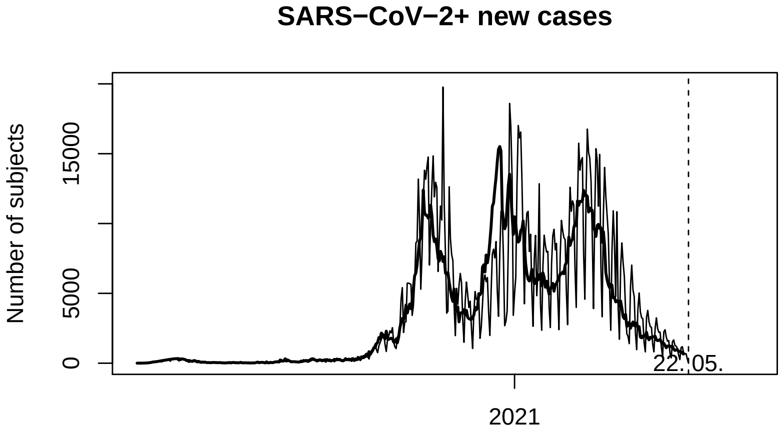
Advantages:

- model estimates ALL the infected

Advantages:



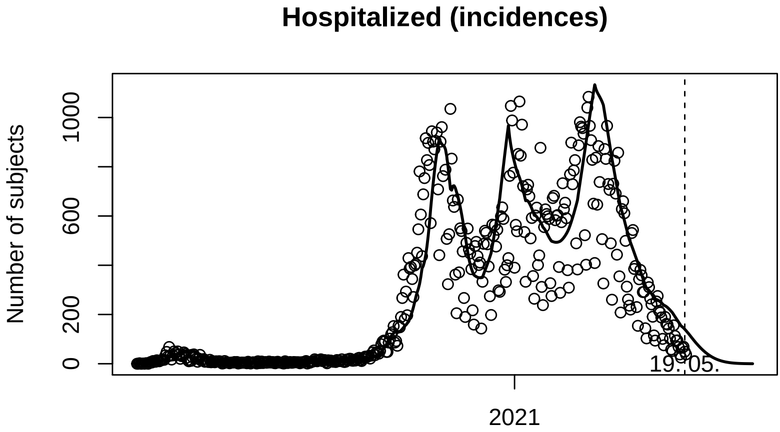
Advantages:


SARS−CoV−2+ new cases
Number of subjects
0
5000
15000
2021
22. 05.

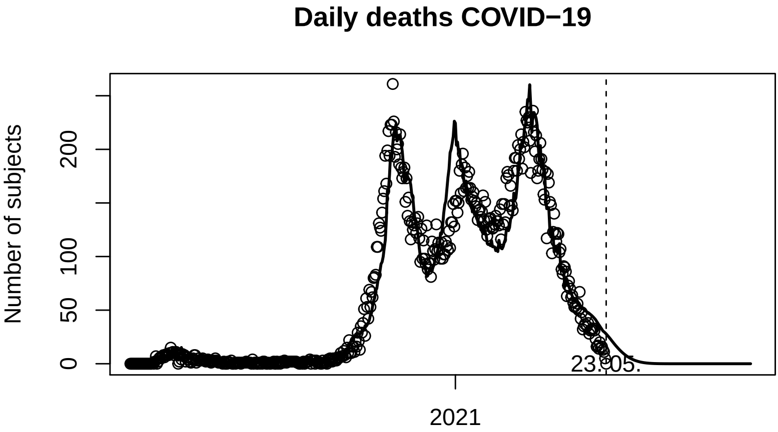
Advantages:

- good estimate for hospitalized cohort

Advantages:


Hospitalized (incidences)
Number of subjects
0
200
600
1000
2021
19. 05.

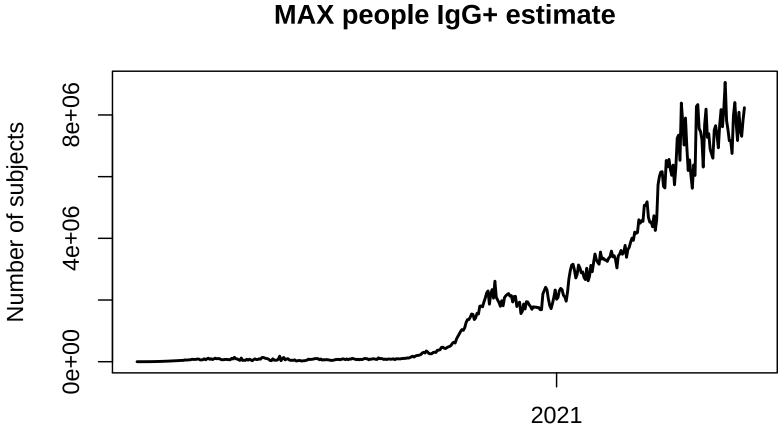
Advantages:


Daily deaths COVID−19
Number of subjects
0
50
100
200
2021
23.05.

Advantages:

- rough estimate of prevalence (herd immunity) under assumption of average IFR around 0.44% for age structure of the Czech Rep. that corresponds to excess deaths data, screening testing and other evidences

Advantages:


MAX people IgG+ estimate
Number of subjects
0e+00
4e+06
8e+06
2021

Limits:

- real time hospitalization data collecting – great in Czechia

Limits:

- real time hospitalization data collecting – great in Czechia
- delay in reported hospitalizations

Limits:

- real time hospitalization data collecting – great in Czechia
- delay in reported hospitalizations
- rapid changes in detection methods

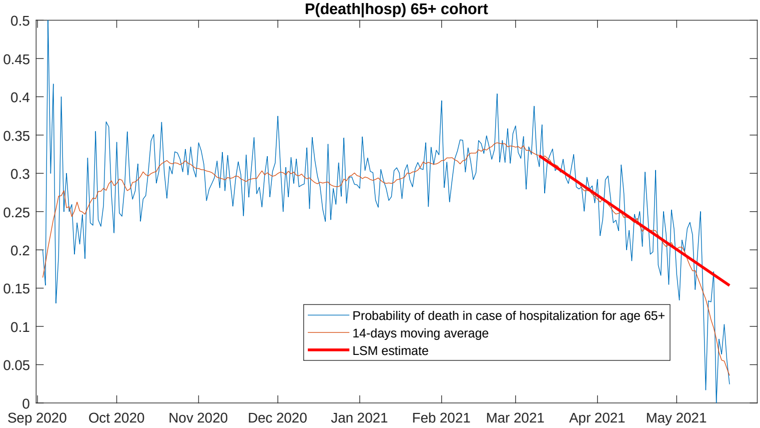
Limits:

- real time hospitalization data collecting – great in Czechia
- delay in reported hospitalizations
- rapid changes in detection methods
- fails for low numbers of hospitalizations

Limits:

- real time hospitalization data collecting – great in Czechia
- delay in reported hospitalizations
- rapid changes in detection methods
- fails for low numbers of hospitalizations
- changes in probability of hospitalizations – new mutations, vaccination, new medical treatment

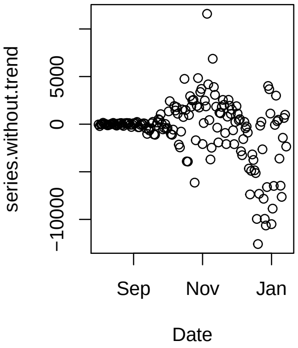
Limits:

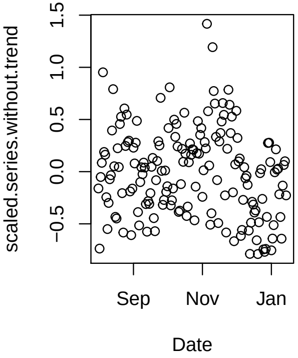


P(death|hosp) 65+ cohort
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Sep 2020
Oct 2020
Nov 2020
Dec 2020
Jan 2021
Feb 2021
Mar 2021
Apr 2021
May 2021
Probability of death in case of hospitalization for age 65+
14-days moving average
LSM estimate

Variability of estimate

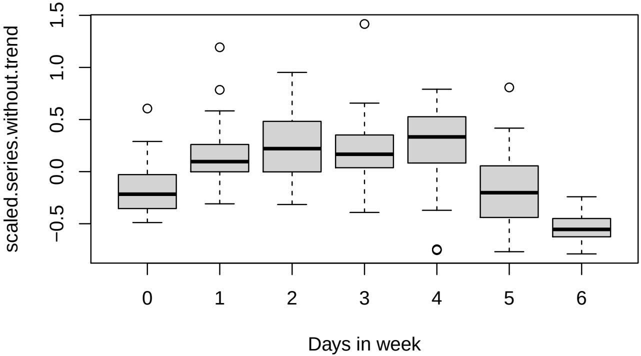
Optimized trend subtracted from real data series:





Variability of estimate

Variability during the week:



Acknowledgements

This work was supported by grants Online platform for real-time monitoring, analysis and management of epidemic situations number MUNI/11/02202001/2020 and Mathematical and statistical modelling number MUNI/A/1615/2020.

Thank You for Your Attention!

MUNI