The Mathematics and Statistics of Infectious Disease Outbreaks

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L12: Monitoring COVID-19 surveillance data time series[1]

[1] LaMo: 2022-05-11 @ 22:08:49

Overview

Overview

1. Introduction
2. Dynamics algorithm
3. Results
4. Discussion

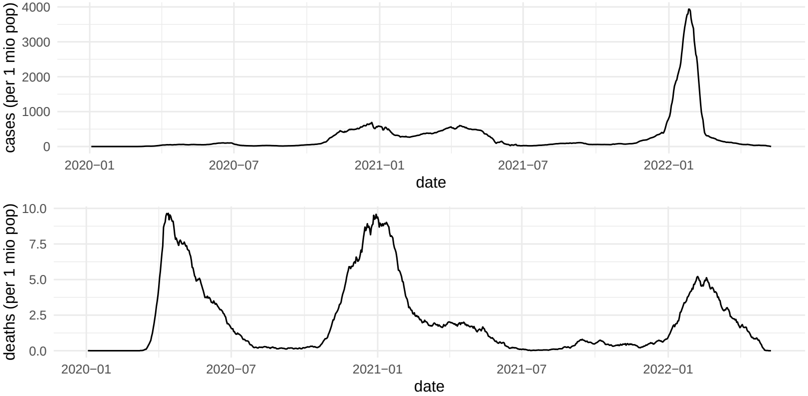
Outline

COVID-19 Monitoring at WHO

- The WHO collects data for 237 countries and presents information about cases, deaths and vaccination in their COVID-19 dashboard
- To achieve situational awareness a quantitative-qualitative process is used to assess the epidemiological trends
- The previous quantitative algorithm was based only on the time series of reported cases; aim was to build a new version using cases and deaths simultaneously

Example: Sweden

Time series of reported cases and deaths (7 day rolling mean)[2]:



[2] Data source: `https://covid19.who.int/data`

Outline

Overview of new dynamics algorithm

Metric

Projected number of deaths during next H weeks (per 1 mio population)

Features:

- Short-term projection of cases using exponential model
- CFR + lag model for the relationship between cases and deaths series
- Obtain projected deaths from case projection using CFR + lag model
- Apply "adjustment factor" to account for discrepancy between reported deaths and "actual" COVID-19 associated deaths
- Threshold resulting avg. daily deaths into one of five categories

Case prediction

- Let T denote the current day (i.e. "now") and let $\tilde{x}_t$ be the time series of reported cases
- Exponential growth model providing predictions based on the observed values of the last, say, 2 weeks:

$$\log(\tilde{x}_t) = \beta_0 + \beta_1 \times t + \epsilon_t = \mu_t^{\tilde{x}} + \epsilon_t, \quad t = T, \ldots T - 13$$

  where $\epsilon_t \overset{\text{iid}}{\sim} N(0, \phi^2)$.
- Robust linear regression is used to fit the model (robustify against zero counts, batch-reporting)
- Fitted model then provides the case predictions $\hat{\tilde{x}}_t$ for $t = T + 1, \ldots T + 7 \cdot H$.

Relating cases and deaths

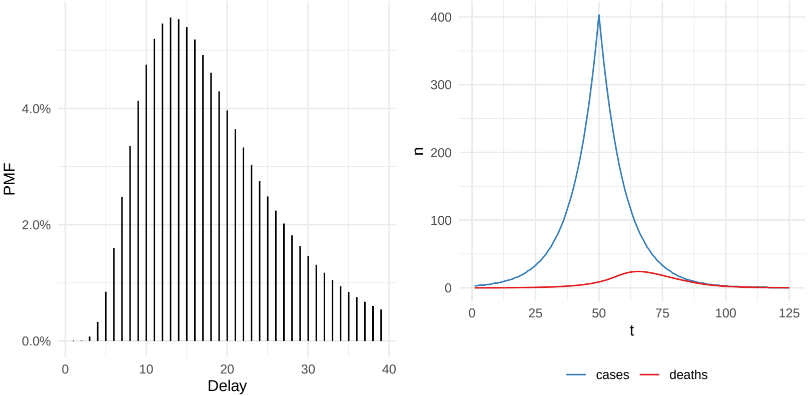
- Relationship between reported cases $\tilde{x}_t$ and reported deaths $\tilde{y}_t$ (each by day of reporting):

$$\mu_t^{\tilde{y}} = E(\tilde{y}_t) = \sum_{s=1}^{\infty} w_s \times \mathrm{CFR}_{t-s} \times \tilde{x}_{t-s}$$

  with $0 \leq w_s \leq 1$ being appropriately scaled weights.
- The w_s correspond to the PMF of the delay. We use a discretized version of $D \sim \mathrm{LogN}(\mu_D, \sigma_D^2)$ for the delay.
- Parameter inference by least-squares using a zero-order spline for CFR_t with equi-distant knots

Example

Example using a discretized log-normal delay with mean 21.8 and CFR $= 10.0\%$:



Adjustment factor

- Relationship between true COVID-19 associated mortalities y_t and reported mortalities $\tilde{y}_t$:

$$\tilde{y}_t = c_t \cdot y_t,$$

- Adjusted mortality projection (as daily avg. per 1 mio population):

$$\hat{z}_T = \frac{1}{7H} \times \frac{\hat{\tilde{y}}_{T+1,T} + \cdots + \hat{\tilde{y}}_{T+7H,T}}{c_T} \times \frac{10^6}{\text{Population}},$$

assuming adjustment-factor is stable the next H weeks

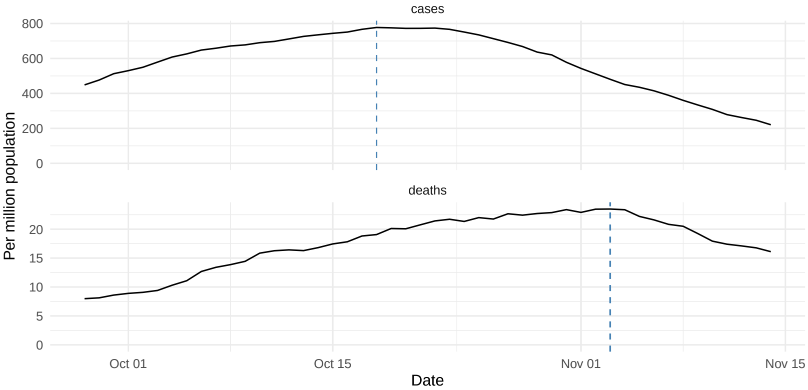
- Classify into one of the 5 classes by thresholding

$$\text{RiskClass}_T = \begin{cases} \text{Minimal} & \text{if } \hat{z}_T < h_1 \\ \text{Low} & \text{if } h_1 \leq \hat{z}_T < h_2 \\ \text{Medium} & \text{if } h_2 \leq \hat{z}_T < h_3 \\ \text{High} & \text{if } h_3 \leq \hat{z}_T < h_4 \\ \text{Very High} & \text{if } \hat{z}_T \geq h_4 \end{cases}$$

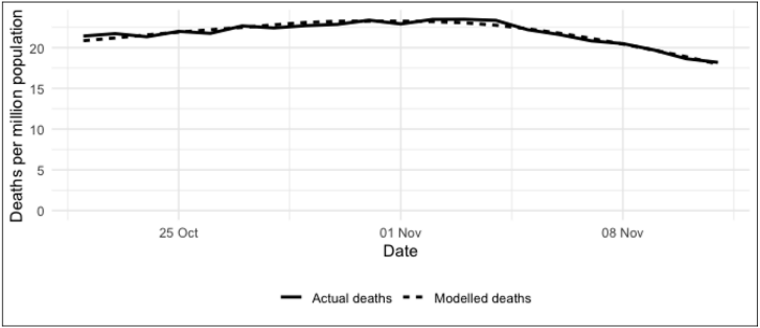
Outline

Time series of reported cases and deaths

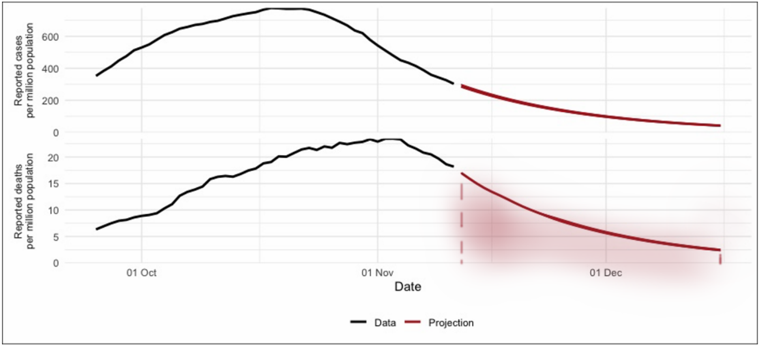
Example country in W45-2021:



CFR + Lag Model fit



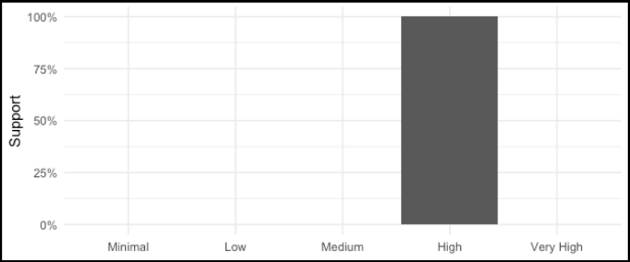
Projected deaths



Final classification

Country summary [redacted]

SOC class	Projected daily deaths (unadjusted)	Projected daily deaths (adjusted)	Adjustment factor	CFR (%)	Mean delay (reporting to death)	Projection horizon (days)
High	7.73 (7.60 - 7.87)	7.84 (7.70 - 7.98)	1.01	3.22	10.87	35



Report Generation

SOC: Epidemiological Dynamics

2021

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Regional summary

EMRO | EURO | AFRO | WPRO | PAHO | SEARO

Show 10 entries

Search:

Country	SOC class	Projected daily deaths (unadjusted)	Projected daily deaths (adjusted)	Adjustment factor	CFR (%)	Mean delay (reporting to death)	Projection horizon (days)
[illegible]	Medium	2.99 (2.80 - 3.19)	5.58 (0.41 - 10.75)	[illegible]	0.92	11.84	35
[illegible]	Medium	0.61 (0.60 - 0.62)	3.40 (0.00 - 8.80)	[illegible]	6.67	5.32	35
[illegible]	Medium	0.15 (0.14 - 0.16)	3.40 (0.00 - 8.07)	[illegible]	2.73	7.60	35
[illegible]	Medium	1.59 (1.56 - 1.62)	2.97 (0.23 - 5.71)	[illegible]	2.13	29.98	35
[illegible]	Medium	0.41 (0.33 - 1.09)	2.28 (0.00 - 6.47)	[illegible]	3.17	24.49	35
[illegible]	Medium	0.10 (0.07 - 0.13)	2.23 (0.00 - 5.37)	[illegible]	5.16	5.60	35
[illegible]	Low	1.02 (1.01 - 1.04)	1.91 (0.15 - 3.68)	[illegible]	1.04	36.69	35
[illegible]	Low	0.93 (0.92 - 0.95)	1.74 (0.13 - 3.35)	[illegible]	1.26	17.06	35
[illegible]	Minimal	0.11 (0.06 - 4.13)	2.38 (0.00 - 48.42)	[illegible]	7.11	11.68	35
[illegible]	Minimal	0.37 (0.33 - 0.40)	2.04 (0.00 - 5.28)	[illegible]	1.80	5.23	35

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Outline

Summary

- The new algorithm was launched 2022-W02 and provides the initial assessment for each of the 237 countries, regions and areas
- Current statistical-methodological improvements
  - Fully Bayesian version linking all stages in one coherent model
  - Nowcasting cases and death time series for countries with back-reporting
  - Integrate damping in trend component of exponential model
  - Supplement adjustment factor choice by expert-knowledge
- Fine-tuning for edge-cases is an ongoing process, important to understand the data generating processes

Acknowledgements

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