AN INITIATIVE OF
THE NETHERLANDS
RED CROSS

FORECASTING COVID-19

[redacted] (10)(2e)

20-mar-2020

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PROBLEM DEFINITION

- Goal: **forecast the number of cases of covid-19**

- Subgoals:
  - when will the peak of infection be?
  - How many people will be hospitalized?

- Possible approaches that we tried:
  1. **Fits** to reported number of cases with **exponential** and **logistic** functions:
     - Pros: very few free parameters, low model variance
     - Cons: valid only for short time scales (<= 1 week)
  2. **Compartmental models** (SIR, SEIR…)
     - Pros: more realistic picture on long time scales (> 1 week)
     - Pros: possible to estimate effects of interventions
     - Cons: many unknown parameters to be estimated

- Methodology reviewed by [redacted], epidemiologist at Wageningen University

N.B. Predictions are **ball park estimates** and the following is **work-in-progress**

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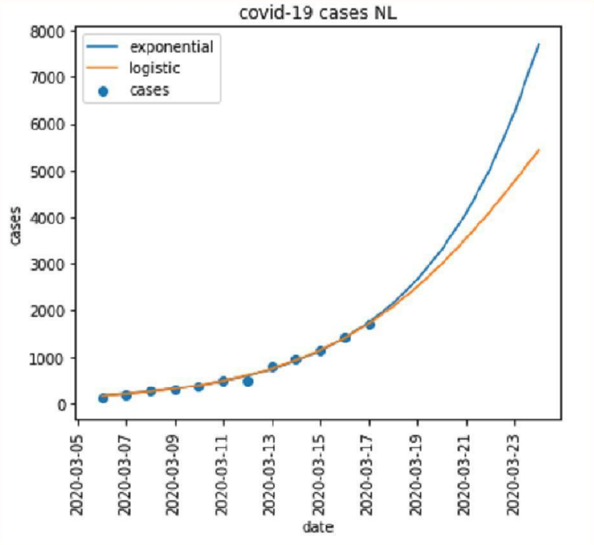
Fits with exponential and logistic (1/2)

exponential

$$f(x) = ab^x$$

logistic

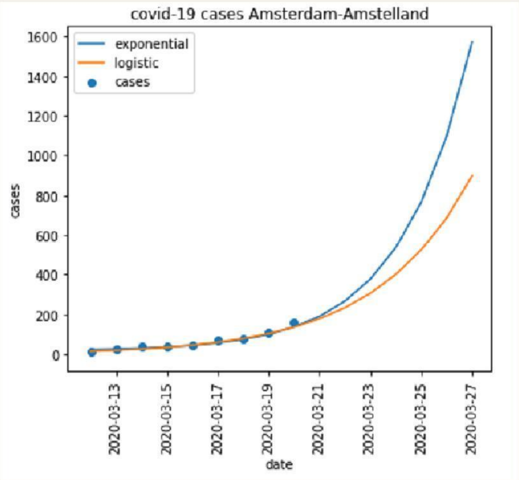
$$f(x) = \frac{L}{1 + e^{-k(x-x_0)}}$$

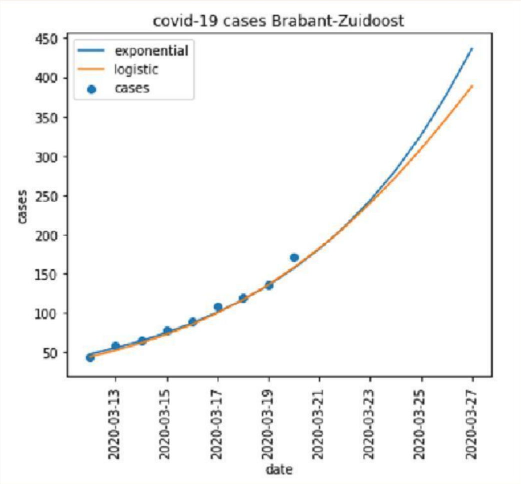


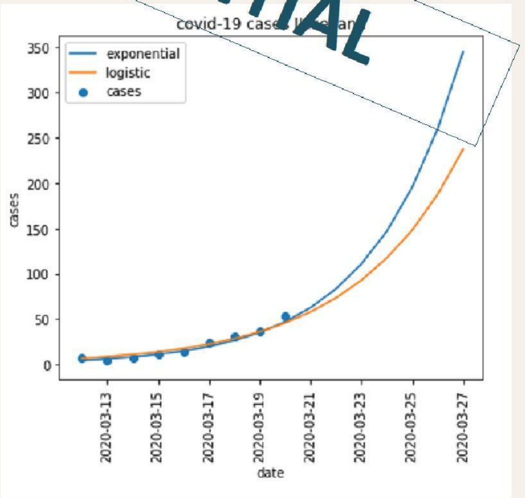
- Exponential and logistic function are **biologically motivated** descriptions of population dynamics (e.g. see *Nature education*)
- They both describe data quite well, both at national (below) and local level (next slide)
- Predictions diverge with time: taking the **average** of exponential and logistic is probably a safe bet
- In order to account for smooth changes in growth as a function of time (e.g. effects of government interventions), **better to fit over the last ~10 days** (enough for 2 free parameters)

Fits with exponential and logistic (2/2)

Good fit also at a local level (e.g. regions in the Netherlands)
Be aware of statistics if not much data is available at a local level: small numbers → big uncertainties







Compartemental models

- Introduction:
  *"**Compartmental models** are a technique used to simplify the mathematical modeling of infectious disease. The population is divided into compartments, with the assumption that every individual in the same compartment has the same characteristics."* (source: Wikipedia)

- For covid-19, the most used ones are variations of a **SEIR model**:
  - Population is divided into
    - susceptible (S): can get the disease
    - exposed (E): got the disease, but still incubating
    - mild infections (I1): mild symptoms
    - severe infections (I1): severe symptoms → hospitalization required
    - critical infections (I1): critical symptoms → intensive care (IC) required
    - recovered (R)
    - dead (D)
  - Dynamics are governed by a series of parameters (transmission rate, death rate, etc.)
  - See more details on Wikipedia or in this presentation

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Compartemental models: parameters

- **Many unknown parameters**, here's a collection of best estimates:
  1. basic reproduction number: 2.3 [source]
  2. basic reproduction number with full lock-down: 1 [source]
  3. incubation period: 5 days [source]
  4. duration of mild infections: 7 days [missing source]
  5. % of severe infections: 14% [source]
  6. % of critical infections: 5% [source]
  7. compartment size: number of people in country/region

- Notes:
  - It's in many cases a '**worst-case-scenario**' because it assumes random mixing (everyone has an equal chance of being in contact with each other). From a virus point of view, that is the most efficient way of spreading around.
  - **Time of the peak** will strongly depend on the compartment size: make sure you have good **population estimates**
  - Simplest implementations of SEIR **do not include age** compartments/classes: important for covid-19, work in progress

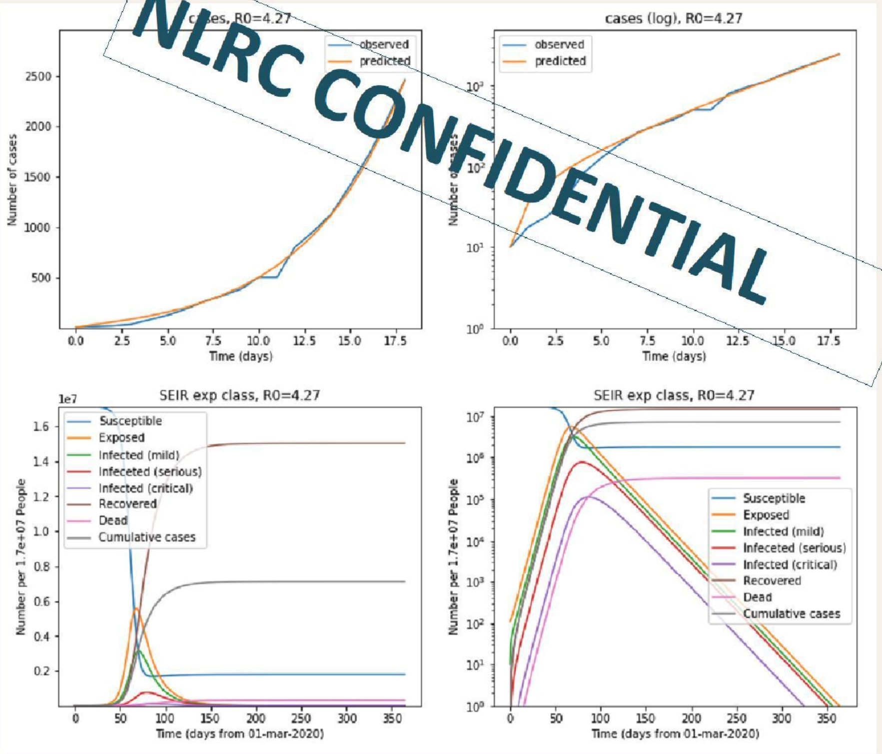
Compartemental models: preliminary results

Preliminary results:

- **Decent description** of early-time evolution of cumulative number of cases in NL
- Evidence for **higher-than-expected transmission rate** (effective R0 ~4)
- **Assuming no interventions**, for a population of about 17M **peak** is expected at **day ~60**, with about 3-5% of people hospitalized

Note:

- Full lock-down in China achieved R0~1, unclear what other interventions will do



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Additional resources

- Python implementation of exponential and logistic fits:
  - https://towardsdatascience.com/covid-19-infection-in-italy-mathematical-models-and-predictions-7784b4d7dd8d

- Web-based tools for SEIR models:
  - Harvard model: https://alhill.shinyapps.io/COVID19seir/
  - ExploSYS model: http://covidsim.eu/

- Python implementation of a SEIR model:
  - https://colab.research.google.com/github/alsnhll/SEIR_COVID19/blob/master/SEIR_COVID19.ipynb

- **ALWAYS CROSS-CHECK WHAT YOU DO WITH AN EPIDEMIOLOGIST**