COVIDHunter: An Accurate, Flexible, and Environment-Aware Open-Source COVID-19 Outbreak Simulation Model

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1. Challenges of Detecting COVID-19 Infections

It is still **extremely challenging** to **detect and isolate** COVID-19 infections at **early stages** due to three key issues:

1) **Variable incubation period:** COVID-19 patients can **develop symptoms between 2 to 14 days** (or longer in a few cases) after exposure to the new coronavirus [Lauer+, AIM 2020] [Li+, NEJM 2020].

2) **Viruses mutate all the time:** The coronavirus genome can exhibit **rapid genetic changes** in its nucleotide sequence [Andersen+, Nature Medicine 2020].

3) **Coronavirus can survive outside the host:** The coronavirus **can survive and therefore remain infectious** outside the host at room temperature for up to 28 days [Kampf+, JHI 2020] [Riddell+, Virology J. 2020].

Hence, **simulating COVID-19 spread** remains one of the most effective ways in managing the healthcare system and guiding policy-makers.

2. Problem

Existing COVID-19 simulation models:

✗ **Account for reporting delays and under-reporting**

✗ **Consider the effects of only mitigation measures**

✗ **Consider both mitigation measures and seasonality using *naive* modeling**

No model is capable of **accurately simulating** the epidemiological situation while accounting for the effects of **environmental conditions** and considering a reasonably **low number of assumptions and model parameters**

3. Our Goal

Our **goal** is to develop such a **COVID-19 outbreak simulation model**.

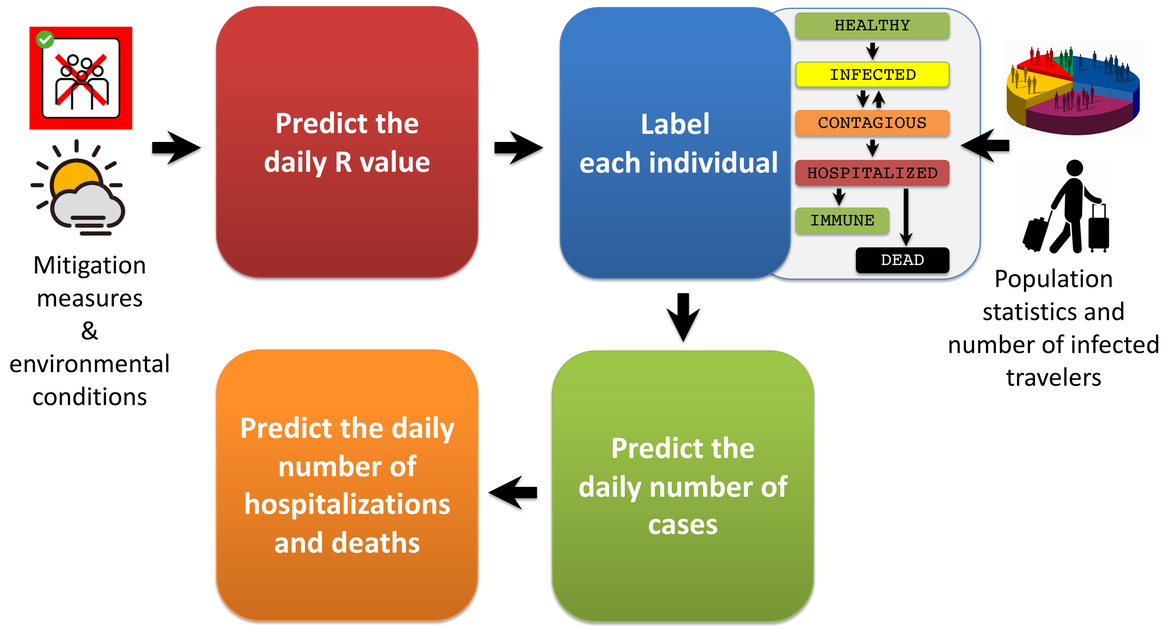
To this end: We introduce COVIDHunter, a **flexible and accurate** COVID-19 outbreak simulation model that evaluates the **mitigation measures** and considers the effect of **environmental conditions**.

4. Key Ideas

✓ Quantifies the spread of COVID-19 in a geographical region by calculating the daily **reproduction number**, R, based on 1) **mitigation measures**, 2) **environmental conditions**, 3) **population clustering** (HEALTHY, INFECTED, CONTAGIOUS, and IMMUNE), and 4) **infected travelers**.

✓ Uses **historical** COVID-19 **hospitalizations-to-cases** and **deaths-to-cases ratios** for calculating the number of hospitalizations and deaths.

5. COVIDHunter Walkthrough



COVIDHunter includes four main steps:

- First, it predicts the **daily reproduction number** using input information about the mitigation measures and environmental conditions. The reproduction number describes the **average number** of new infections caused by each **infected person**.
- Second, it **labels** each individual in a population according to **different stages of the COVID-19** infection timeline. This step uses input information about the **population** and **infected travelers** (such as cross-boarder travelers).
- Third, it predicts the daily number of cases. The model initially considers the entire population as **uninfected**. It then decides how many persons can be INFECTED during a given day based on the **reproduction number value**.
- Fourth, it predicts the daily number of hospitalizations and deaths using **historical** COVID-19 **hospitalizations-to-cases** and **deaths-to-cases ratios**.

6. Evaluation & Key Takeaways

We use **Switzerland** as a use-case for all the experiments. However, our model is **not limited to any specific region** as the parameters it uses are completely configurable.

We **benchmark** our model against **prominent alternative models** of the COVID-19 pandemic that are used to assist governments:

- **United Kingdom, ICL** [Flaxman+, Nature 2020].
- **United States, IHME** [Reiner+, Nature Medicine 2020].
- **Switzerland, IBZ** [Huisman+, medRxiv 2020]
- **LSHTM** [Russell+, BMC Medicine 2020].

✓ Compared to prominent policy-making models (IBZ, LSHTM, ICL, and IHME), **COVIDHunter achieves more accurate estimation** and provides **no prediction delay**.

✓ For each **1◦C rise in daytime temperature**, there is a **3.67% decrease** in the daily number of confirmed cases.

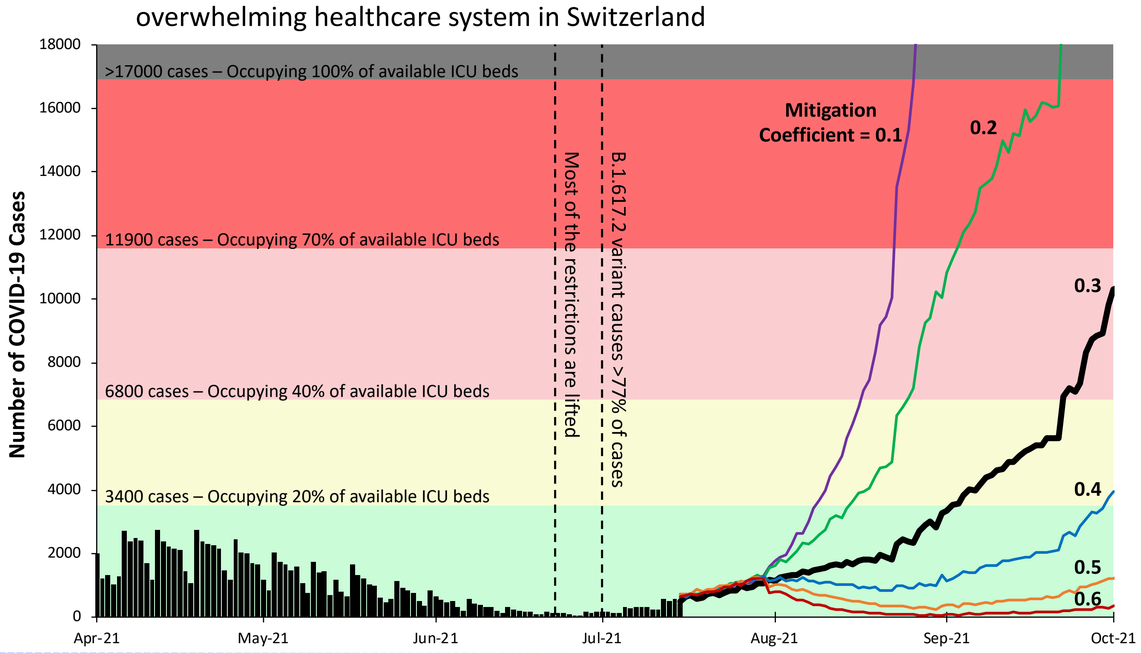
✓ **Easy to use** and **flexible to configure** due to the **simple** modeling approach that uses a **small number** of parameters.

✓ **COVIDHunter** is **open-source** & well-documented:

medRxiv GitHub Data Visualization

The Summer of 2021 is different in Switzerland

- We study the effect of **changing the strength of the mitigation measures** applied in Switzerland during **August 2021**
- The **mitigation coefficient** has a value between 0 and 1, where 1 represents the **strongest** mitigation measure and 0 represents **no** mitigation measure applied.
- **COVIDHunter** forecasts that:
  - The current **mitigation measures** applied in Switzerland are of **strength 0.3**
  - We **cannot afford** further **relaxation** of mitigation measures
  - **Further tightening of mitigation measures** is needed **before October 2021** to avoid overwhelming healthcare system in Switzerland



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