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] [LH, 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.

5. 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].
- 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

6. Key Takeaways
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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