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

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Executive Summary

**Problem:** 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.

- **No future prediction:** Accounting for reporting delays and under-reporting due to inefficiencies such as low number of COVID-19 tests.
- **Inaccurate prediction:** Don’t rely on the observed (laboratory-confirmed) number of cases, lack environment-awareness, and require a large number of assumptions and various input parameters.

**Goal:** Develop such a COVID-19 outbreak simulation model.

**COVIDHunter:**

- **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.

**Key results:**

- Compared to prominent policy-making models (IBZ, LSHTM, ICL, and IHME), COVIDHunter achieves more accurate estimation and provides no prediction delay.
- For each $1^\circ$C rise in daytime temperature, there is a 3.67% decrease in the daily number of confirmed cases.
- COVIDHunter is easy to use and flexible to configure due to the simple modeling approach that uses a small number of parameters.
How Does COVIDHunter Work?

Mitigation measures & environmental conditions

Predict the daily R value

Label each individual

Predict the daily number of hospitalizations and deaths

Predict the daily number of cases

Population statistics and number of infected travelers

R describes the average number of new infections caused by each infected person
Epidemiological Situation in Switzerland

- We use Switzerland as a use-case for all the experiments.
  - COVIDHunter is completely configurable for other countries:
    - [https://github.com/CMU-SAFAI/COVIDHunter/tree/main/Reproduce-Switzerland-Case-Study-Results](https://github.com/CMU-SAFAI/COVIDHunter/tree/main/Reproduce-Switzerland-Case-Study-Results)

- Workloads
  - Data and source code: [https://github.com/CMU-SAFAI/COVIDHunter](https://github.com/CMU-SAFAI/COVIDHunter)
  - Simulation runs and visualization: [https://mealser.github.io/COVIDHunter/](https://mealser.github.io/COVIDHunter/)

- Comparison points
  - Prominent simulation models used to assist in decision-making for policy-makers in countries:
    - United Kingdom, ICL [Flaxman+, Nature 2020].
    - Switzerland, IBZ [Huisman+, medRxiv 2020]
    - LSHTM [Russell+, BMC Medicine 2020].
Mitigation measures applied during the summer of 2020 are only 14% more relaxed compared to the mitigation measures applied during the first wave, which is implausible.
ICL model provides overestimated number of COVID-19 cases (3.8× compared to $\text{CTC}_{100}\%\text{M}(t)=0.7$) as demonstrated using two different simulation runs, January 2021 and April 2021.
ICL model and IHME model overestimate the number of hospitalizations (18.6× and 10.6× higher than the observed number of hospitalizations), using January and April 2021 simulation runs, respectively, which is highly unlikely.
ICL and IHME models provide late prediction (their curves are shifted by 5-10 days from that of other models).
COVIDHunter 2.0

- Support for a mutated virus with a different R0 value.
- Support for asymptomatic cases.
- Support for vaccinations.

Compatible with COVIDHunter 1.0

- The reproduction number, R.
- The number of infected persons.
- The number of hospitalized persons.
- The number of deaths.
- The number of individuals at each stage of the COVID-19 infection (healthy, infected, contagious, and immune).
- The strength and the duration of each mitigation measure.

https://github.com/CMU-SAFARI/COVIDHunter
The Summer of 2021 is different in Switzerland

The effect of changing the strength of the mitigation measures applied in Switzerland during August 2021

>17000 – Occupying 100% of available ICU beds

11900 – Occupying 70% of available ICU beds

6800 – Occupying 40% of available ICU beds

3400 – Occupying 20% of available ICU beds

COVIDHunter forecasts that further tightening of mitigation measures is needed before October 2021 to avoid overwhelming healthcare system in Switzerland.
COVIDHunter: An Accurate, Flexible, and Anonymous Tool for Simulating and Analyzing the Impact of COVID-19 Spread in Populations

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Simulation runs and visualization: [https://mealser.github.io/COVIDHunter/](https://mealser.github.io/COVIDHunter/)

Daily Number of COVID-19 Cases
February 2020 - August 2021

Expected Cases
- COVIDHunter-CTC_100% M(t)=0.4
- COVIDHunter-CTC_100% M(t)=0.6
- COVIDHunter-CTC_50% M(t)=0.35
- COVIDHunter-CTC_50% M(t)=0.5
- COVIDHunter-CTC_50% M(t)=0.7
- ICL
- IHME

COVIDHunter-CTC_100% M(t)=0.35
07.07.21
COVIDHunter-CTC_100% M(t)=0.35: 77

Prediction

[SAFARI]
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