Simulating disease outbreaks to prepare for future pandemics

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Preparation for pandemics

- Rapid response and community awareness are critical for disease control efforts
- Mathematical models are essential to anticipate the best interventions to use during a pandemic
- We don't want to wait for a real pandemic to learn how to best respond

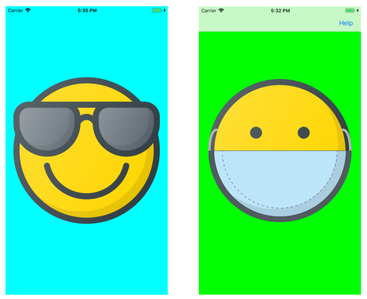
A teaching tool that realistically simulates an outbreak is critical to teach people the effectiveness of interventions and the genetics involved in the preparation and analyses of outbreaks.

Building an app that simulates a pathogen through Bluetooth

Introducing Operation Outbreak (O2)

Healthy/Susceptible **Sick/Infectious** **Recovered**

The O2 app keeps track of the health status of each participant in the simulation.

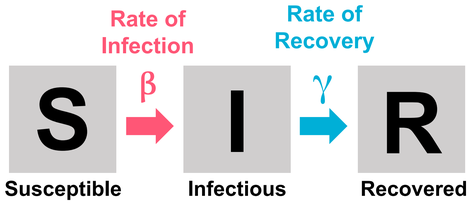


Vaccinated **Masked**

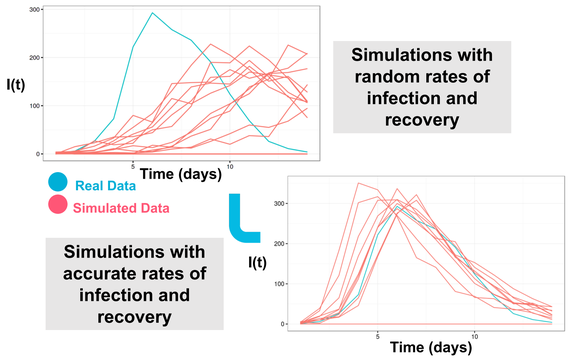
The O2 app adjusts the status of participants based on user actions such as receiving a vaccination or putting on a mask, making it impossible or less likely that they get infected, respectively.

Simulating Realistic Data

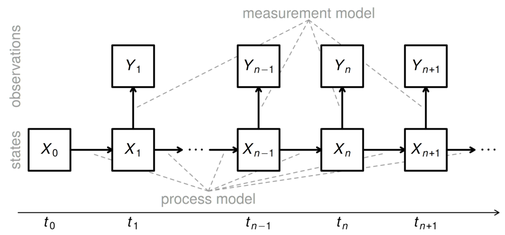
SIR Models Represent Disease Outbreaks



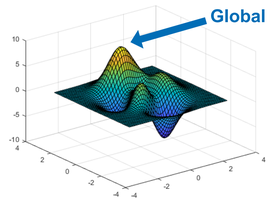
SIR models are used to mathematically model the change in the number of susceptible, infectious, and recovered individuals over time.



Partially observed Markov process (POMP) model captures the reality of underreported data



Iterated filtering explores the space of parameters and finds the optimal set

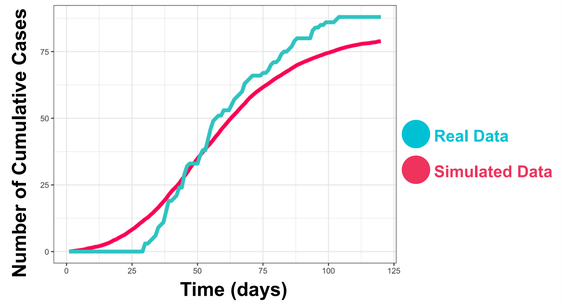


Find global maximum by maximizing the likelihood function:

$$\mathcal{L}(\theta) = \mathrm{P}(y^*_{1:N} \mid \theta)$$

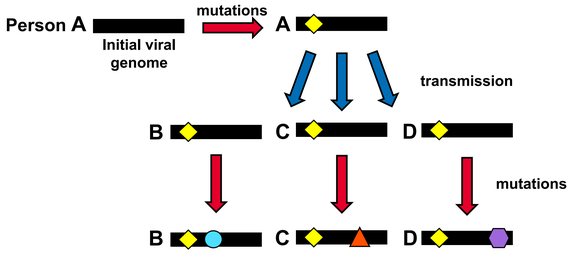
Let θ be the set of parameters.

Successfully constructed our POMP model



Integrating Pathogen Evolution

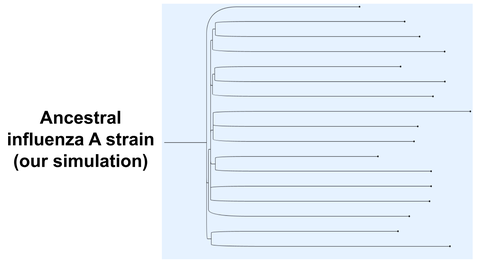
- Genetic sequencing is taking center stage in diagnostics
- Viruses mutate and evolve into different strains
- Specific strains determine courses of treatment



Our evolutionary model assumes that the viral genome mutates daily in each infected individual and infected individuals transmit their current viral genomes when they infect susceptibles. We are using substitution rates to mutate the genomes.

Participants will analyze the genetic data with:

- BLAST – for genetic diagnostics
- BEAST, IQ-TREE – for evolutionary and phylogenetic analyses



Main Takeaways

- To ensure we are ready for the next pandemic, we need an interactive teaching tool that can simulate realistic disease outbreaks
- Implementing POMP and iterated filtering to simulate epidemiological models allows users to run their own, custom simulations
- Simulating pathogen evolution, which results in sequence diversity, gives participants realistic genetic data

Future Work

- Implement both the POMP and evolutionary models in iOS
- Construct a user friendly interface for the genetic analysis portion of the app

References

King, Aaron, Dao Nguyen, & Edward L. Ionides. "Statistical Inference for Partially Observed Markov Processes via the R Package pomp." *Journal of Statistical Software* [Online], 69.12 (2016): 1 - 43. Web. 30 Jul. 2019. doi: 10.18637/jss.v069.i12

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