Epidemiological SIR-models for predicting infectious diseases

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Background

• COVID-19 pandemic still has a huge effect on the world
• Non-pharmaceutical intervention (NPI) strategies and vaccines are being used across the globe
• How to estimate the impact of these intervention and vaccination strategies
Goals

• SIR-modeling and COVID-19
• How informative is SIR-modeling as a prediction tool
• Study how extended SIR-models that are used to model vaccination
• Understand the limits of simple modeling (Lahtinen et al. 2017)
Methods

- Detailed review of 8 research papers
- Illustrative SIRV-model implemented in MATLAB

Table 1: Main models used in the research papers listed and the main problems the research is trying to tackle
Basic SIR-model

\[
\begin{align*}
\frac{dS}{dt} &= -\beta SI \\
\frac{dI}{dt} &= \beta SI - \gamma I \\
\frac{dR}{dt} &= \gamma I
\end{align*}
\]

Luz et al. 2010
Extended SIR-model(s) 1/2

• Extended SIR-models cover additional phenomena
• Implemented by adding one or more compartments with respective differential equations and transition rates
  – Common ones are E(exposed), Q(quarantined), V (vaccinated), D(dead)
Extended SIR-model(s) 2/2

- Limitations of basic SIR-models can be addressed by extending them.
- Predictions using SIR-models work short term but inaccurate predicting over longer periods of time.
- Vaccination policies matter:
  - Vaccine prioritization vs vaccination speed (Agarwal et al. 2021)
  - Vaccine efficacy (Bubar et al. 2020)
  - Vaccine release time (Yu et al. 2016)
Illustrative modeling example

- SIRV over 300 days, 50 infected at day 0, total population 5.5 million, parameters constant
- Vaccine efficacy 100%, one dose guarantees protection, no delay from vaccination to effect
- 4 vaccination scenarios
  - Upfront (vaccinating on day 1)
  - Periodical (vaccinating on 4 occasions)
  - Constant (vaccinating everyday)
  - Response (vaccinating as a response to a infection peak)
Results

Figure 1: Result of the simulation when vaccinating on day 1
Results

Figure 2: Result of the simulation when vaccinating on 4 occasions
Results

Figure 3: Result of the simulation when vaccinating every day
Results

Figure 4: Result of the simulation when vaccinating as a response to a infection peak
Summary

• SIR-modeling is a flexible and a simple tool
• SIR-models describe the main features in the evolution of infectious diseases
• ”All models are wrong but some are useful” (George Box)
• Improvements or alternatives to SIR-modeling
  – IBM (Individual-based models)
  – Hybrid models
References


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