De verspreiding van COVID-19 begrijpen:
de rol van AI

Robert Kooij
2 November 2020
Who am I?

1988 - 1993

1994 - 1996

Royal Dutch Telecom
1997 - 2003

2003 - 2018

2005 - ...

2018 - 2020

TNO

SUTD
SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN
Do you know who this is?

- Prof. Neil Ferguson
  - Mathematical epidemiologist at Imperial College London
  - Scientific Advisor to UK Government
Prediction: based upon mathematical models

No action taken  ➡️  500,000 deaths in UK!
MATHEMATICS

exponential growth \( R_0 \)
moving averages flattening the curve

the R-number
Importance of understanding spread

- Intervention policy
- Healthcare allocation
- Economic impact
- Mental well-being
Two types of approaches

• Approach 1: Compartmental models
  • Population divided into categories

• Equation based

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

• Agent based
Two types of approaches

- Approach 2: AI-driven models
Overview

- Compartmental models: Equation Based
- Compartmental models: Agent Based
- AI-driven models
- Comparing the approaches
- Equation based approach on networks
- TU Delft COVID-19 Digital Campus
- Wrap-up
Compartmental models: equation based

- **SIR - model**
  - No births or immigration
  - Curing leads to immunity
  - Fixed infection rate per day: $\beta$
  - Fixed recovery time: $1/\gamma$
  - People are well-mixed
Compartmental models: equation based

- S: fraction of population that is **Susceptible**
- I: fraction of population that is **Infected**
- R: fraction of population that is **Removed**

\[
\frac{dS}{dt} = -\beta SI \\
\frac{dI}{dt} = -\gamma I + \beta SI \\
\frac{dR}{dt} = \gamma I
\]

Compartmental models: equation based

fraction of population that is Infected

Exponential growth

capacity healthcare
Compartamental models: equation based

- Growth governed by $R_0$: basic reproduction number
- $R_0$: # of new infections due to first infection
  - $R_0 > 1$: exponential growth # of infections
  - $R_0 = 1$: # of infections stays constant
  - $R_0 < 1$: # of infections decreases fast to 0
- **Flattening the curve**: lowering $R_0$
Compartamental models: equation based

\[ R_0 = \frac{\beta}{\gamma} = p \cdot c \cdot \frac{1}{\gamma} \]

- Probability of infection per contact
- Number of contacts per day
- Duration of infection
- Mask wearing
- Social distancing
- Better treatment
Compartmental models: equation based

- Reduce number of contacts per day by 50%
Compartmental models: equation based

https://ncase.me/covid-19/
Compartmental models: equation based

**Predictive Monitoring of COVID-19**
Jianxi Luo, Singapore University of Technology and Design, May 2020

- Use data on daily number of infections
- Estimate $\beta$ and $\gamma$ by using AI
Infection rate $\beta$ increases after relaxation interventions

Threefold increase of $\beta$
Compartmental models: equation based

4th May
Imperial College COVID-19 Response Team

Report 20: Using mobility to estimate the transmission intensity of COVID-19 in Italy: A subnational analysis with future scenarios

Piedmont

Moebility held constant  Increased mobility: 40% return to pre-lockdown level
Compartmental models: equation based

- Parameters are not constant
- Availability and quality of data
- Undetected cases
- Infection delay
- Duration immunity
- Seasonal variation
- Heterogeneous mixing
- Human factors
Compartmental models: Agent Based

- Each individual (agent)
  - Moves around
  - Is in one of the S-I-R states
Compartmental models: Agent Based

Baseline simulation

2000 people
3% infection risk when near infected person
baseline mortality: 2%
at-risk age: 55+
critical risk age: 75+
healthcare capacity: 300 beds

• Paul van Gent: post-doc at Faculty of CiTG
https://github.com/paulvangentcom/python_corona_simulation
Compartmental models: Agent Based

Modelling transmission and control of the COVID-19 pandemic in Australia

Sheryl L. Chang\textsuperscript{1}, Nathan Harding\textsuperscript{1}, Cameron Zachreson\textsuperscript{1}, Oliver M. Cliff\textsuperscript{1}, and Mikhail Prokopenko\textsuperscript{1,2,*}

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\textsuperscript{2}Marie Bashir Institute for Infectious Diseases and Biosecurity, University of Sydney, Westmead, NSW 2145, Australia
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- Virtual Australia with 24 million agents
  - Demography
  - Mobility
  - Disease
Compartmental models: Agent Based

• Requires massive computation power
• Hard to calibrate

• Once the model is calibrated
  • Relate interventions to changes in infection rates
  • Assess impact of several interventions
Compartmental models: Agent Based
AI-driven models

Inputs:
- Virus mutations
- Demographics
- Mobility
- Mask wearing
- Medical capacity
- Social media
- Amount of testing
- Incubation time

Outputs:
- Case numbers
- Hospitalizations
- ICU beds required
- Fatalities
AI-driven models

AI Predicts Coronavirus Could Infect 2.5 Billion And Kill 53 Million. Doctors Say That’s Not Credible, And Here’s Why
AI-driven models

DeepCOVIDNet: An Interpretable Deep Learning Model for Predictive Surveillance of COVID-19 Using Heterogeneous Features and Their Interactions

ANKIT RAMCHANDANI¹, CHAO FAN¹², AND ALI MOSTAFAVI¹²
¹Department of Computer Science and Engineering, Texas A&M University, College Station, TX 77840, USA
²Zachry Department of Civil and Environmental Engineering, Texas A&M University, College Station, TX 77840, USA
AI-driven models

- Obtain data
- Selecting features
  - Population attributes
  - Population activities
  - Mobility
  - Disease spread attributes
- Build Deep Learning model (LSTM)
- Evaluate performance of model
AI-driven models

- Predictive performance: 7 days
**AI-driven models**

- Identification most influential features
Comparing the approaches

- **Compartment Models**
  - Relatively simple tool for long-term forecasts
  - Parameter estimation

- **Agent Based Models**
  - Lot of work to build
  - Tricky to calibrate

- **AI-driven models**
  - Short-term predictions
  - Unreliable when conditions change
Comparing the approaches

- Hybrid models
- More compartments
  - Undetected cases
  - Hospitalization
  - Incubation delay
- Time dependent control measures
- Parameters estimated through AI

[Mathematical modeling of the spread of the coronavirus disease 2019 (COVID-19) taking into account the undetected infections. The case of China](https://doi.org/10.1002/num.21894)
Comparing the approaches
Comparing the approaches

\[
\frac{dS}{dt}(t) = -\frac{S(t)}{N} \left( m_E(t) \beta_E E(t) + m_I(t) \beta_I I(t) + m_{I_u}(t) \beta_{I_u}(\theta(t)) I_u(t) \right) \\
- \frac{S(t)}{N} \left( m_{H_R}(t) \beta_{H_R}(t) H_R(t) + m_{H_D}(t) \beta_{H_D}(t) H_D(t) \right),
\]

\[
\frac{dE}{dt}(t) = \frac{S(t)}{N} \left( m_E(t) \beta_E E(t) + m_I(t) \beta_I I(t) + m_{I_u}(t) \beta_{I_u}(\theta(t)) I_u(t) \right) \\
+ \frac{S(t)}{N} \left( m_{H_R}(t) \beta_{H_R}(t) H_R(t) + m_{H_D}(t) \beta_{H_D}(t) H_D(t) \right) - \gamma_E E(t) + \tau_1(t) - \tau_2(t),
\]

\[
\frac{dI}{dt}(t) = \gamma_E E(t) - \gamma_I(t) I(t),
\]

\[
\frac{dI_u}{dt}(t) = (1 - \theta(t)) \gamma_I(t) I(t) - \gamma_{I_u}(t) I_u(t),
\]

\[
\frac{dH_R}{dt}(t) = \theta(t) \left( 1 - \frac{\omega(t)}{\rho(t)} \right) \gamma_I(t) I(t) - \gamma_{H_R}(t) H_R(t),
\]

\[
\frac{dH_D}{dt}(t) = \omega(t) \gamma_I(t) I(t) - \gamma_{H_D}(t) H_D(t),
\]

\[
\frac{dR_a}{dt}(t) = \gamma_{H_R}(t) H_R(t),
\]

\[
\frac{dR_u}{dt}(t) = \gamma_{I_u}(t) I_u(t),
\]

\[
\frac{dD}{dt}(t) = \gamma_{H_D}(t) H_D(t).
\]
Comparing the approaches
occur, the number of deaths averted is likely to be considerably lower in both scenarios. It should be noted that in our model we do not account for cross-region movement, which, given increased mobility, is likely to increase infections and subsequently deaths, in regions not experiencing major epidemics.
Equation based approach on networks

https://www.nas.ewi.tudelft.nl/index.php/coronavirus
**Equation based approach on networks**

- NIPA = Network Inference-based Prediction Algorithm

- For every province estimate
  - Self-infection and curing rate
  - Infection to other provinces

156 parameters! Estimated using AI
Equation based approach on networks
Equation based approach on networks
TU Delft – COVID-19 Digital Campus

COVID-19 Digital Campus
A living lab for digital technologies
TU Delft – COVID-19 Digital Campus

1. Campus Mobility Dashboard
   Insights, analysis, simulations

2. Well-being
   Informing & engaging students and staff

3. Leveraging Contact networks
   Improve prediction of virus spread

Sensor network, TU Delft data sources, 3rd party data sources

https://www.tudelft.nl/en/covid/
Wrap-up

- Importance of understanding COVID-19 spread
- Equation based approach
- Agent Based approach
- AI-driven approach
- Hybrid models
- COVID-19 Digital Campus
Wrap-up

29 October 2020

Report 34: COVID-19 Infection Fatality Ratio: Estimates from Seroprevalence

Nicholas F Brazeau¹, Robert Verity¹, Sara Jenks², Han Fu¹, Charles Whittaker¹, Peter Winskill¹, Ilaria Dorigatti¹, Patrick Walker¹, Steven Riley¹, Ricardo P Schnekenberg³, Henrique Hoeltgebaum⁴, Thomas A Mellan¹, Swapnil Mishra¹, H Juliette T Unwin¹, Oliver J Watson¹, Zulma M Cucunubá¹, Marc Baguelin¹, Lilith Whittles¹, Samir Bhatt¹, Azra C Ghani², Neil M Ferguson¹, Lucy C Okell¹⁺.
Thanks for your attention!

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