Spatial simulation of infectious diseases

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Reading

Neuwirth, C., Gruber, C., & Murphy, T. (2020). Investigating duration and intensity of Covid-19 social-distancing strategies. *Scientific Reports*, *10*(1).

Neuwirth, C., & Gruber, C. (2022). Investigation of turning points in the effectiveness of Covid-19 social distancing. *Scientific Reports*, *12*(1).

Contents

1. Disease outbreak parameters and misperceptions

2. SIR Network Model
   - Implementation
   - Limitations
   - Lessons learned

3. Geosimulation: Corona outbreak in a refugee camp
   - Limitations
   - Lessons learned

Misperception 1

Kein Grund zur Sorge wegen des Coronavirus in Europa (Der Standard, January 2020)

*„Derzeit wird davon ausgegangen, dass eine **infizierte Person zwischen drei und fünf weitere Menschen** ansteckt. 2019-nCoV ist aber deutlich weniger gefährlich als der Sars- oder Mers-Erreger. Die **Sterblichkeitsrate liegt bei maximal drei Prozent**…“*

*„Trotz eines wahrscheinlichen Imports von vereinzelten Infizierten werde es hierzulande mit hoher Wahrscheinlichkeit "**keine signifikante Gefährdung**" durch 2019-nCoV geben, sagt Clemens Wendter, Infektiologe an der München Klinik Schwabing…“*

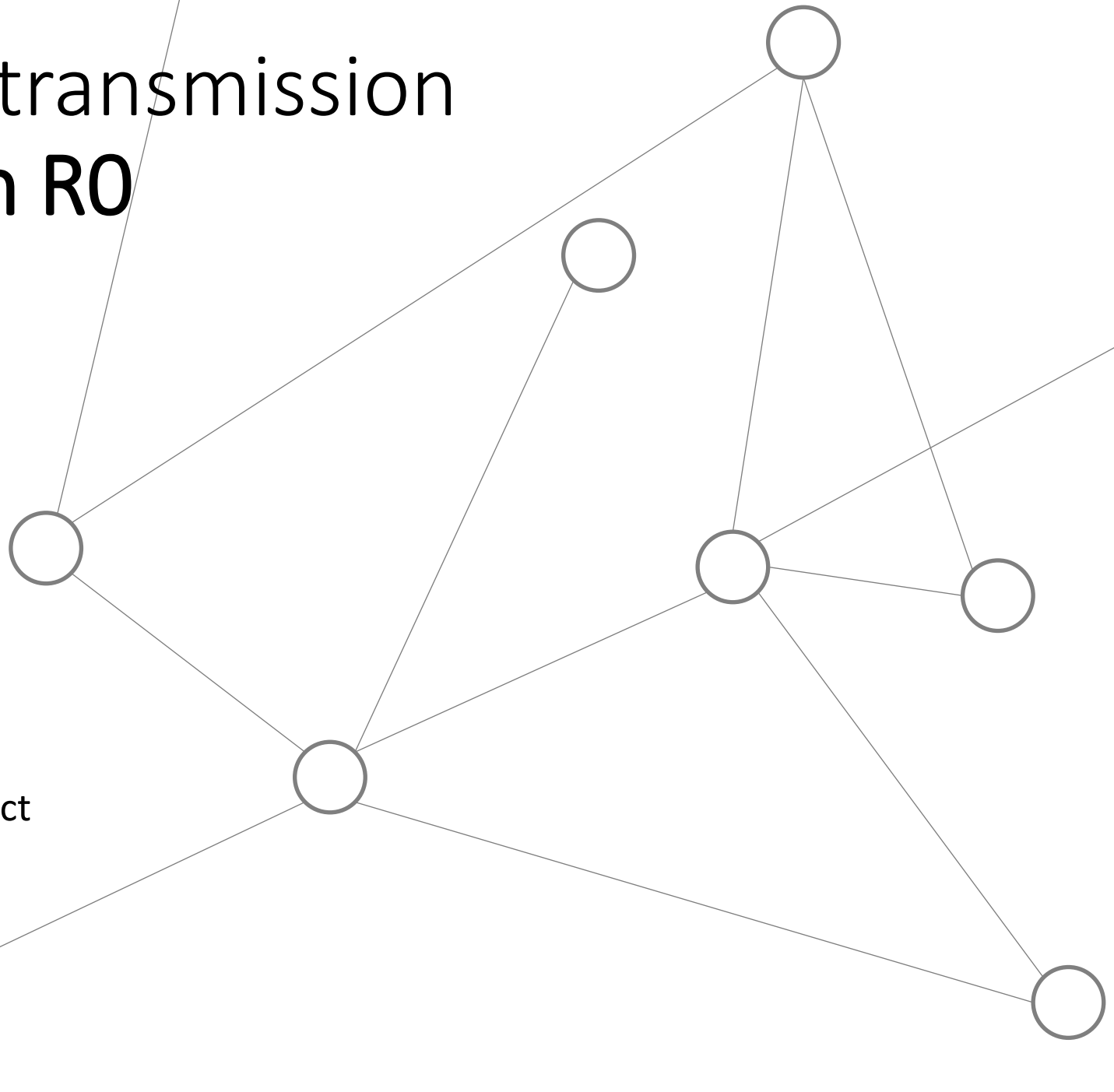
Human to human transmission
Basic Reproduction R0

1.5 (95% CI: 1.4–1.6) (Shim et al., 2020)

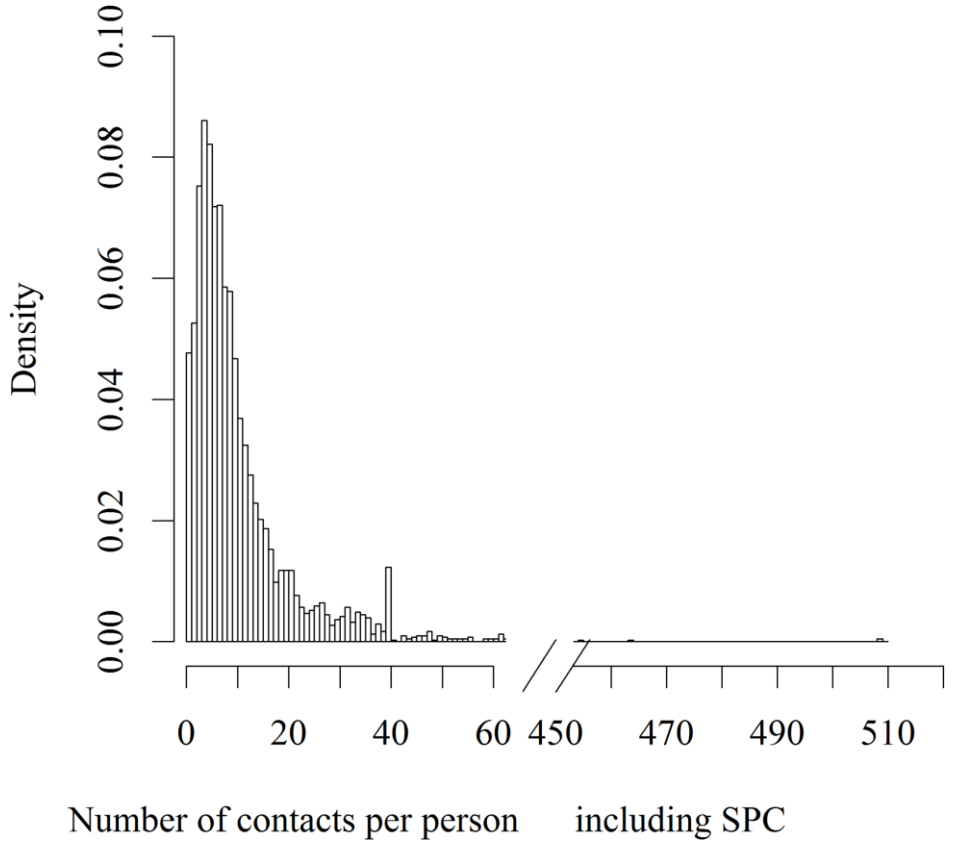
Up to **8.7** (Linka et al., 2020)

Three important parameters:

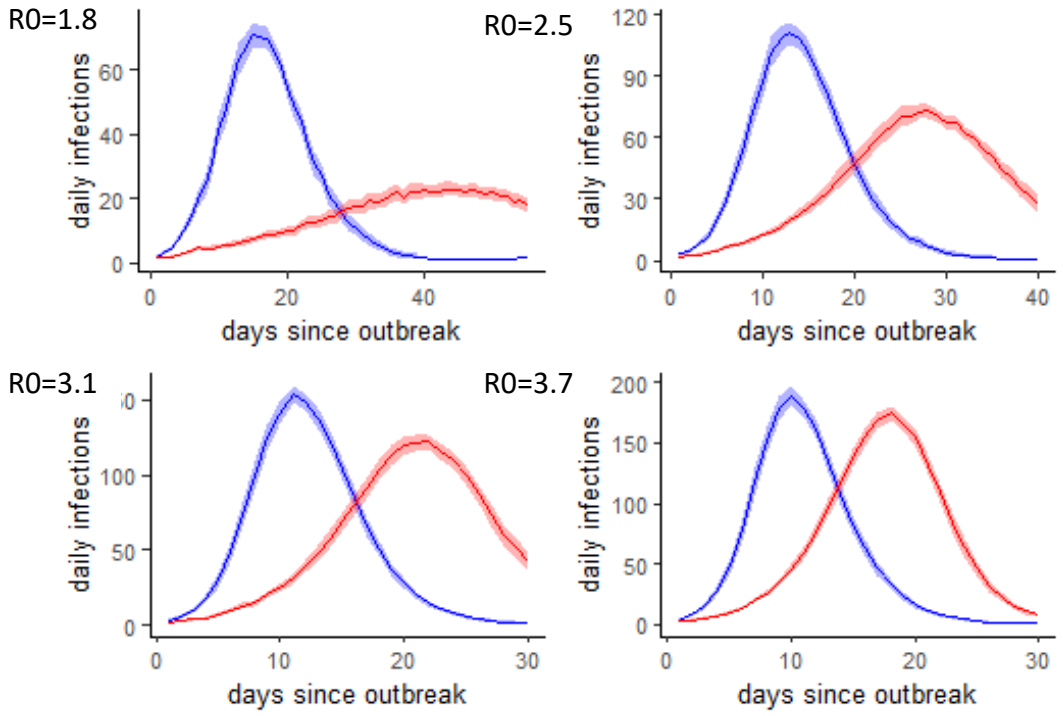
1. Duration of infectiousness
2. Infectiousness or probability to infect
3. Social contacts per time interval



Human to human transmission
Basic Reproduction R0



Béraud et al. (2015)



blue…simulation based on empirical social contact survey
red…simulation base on uniform node degree model

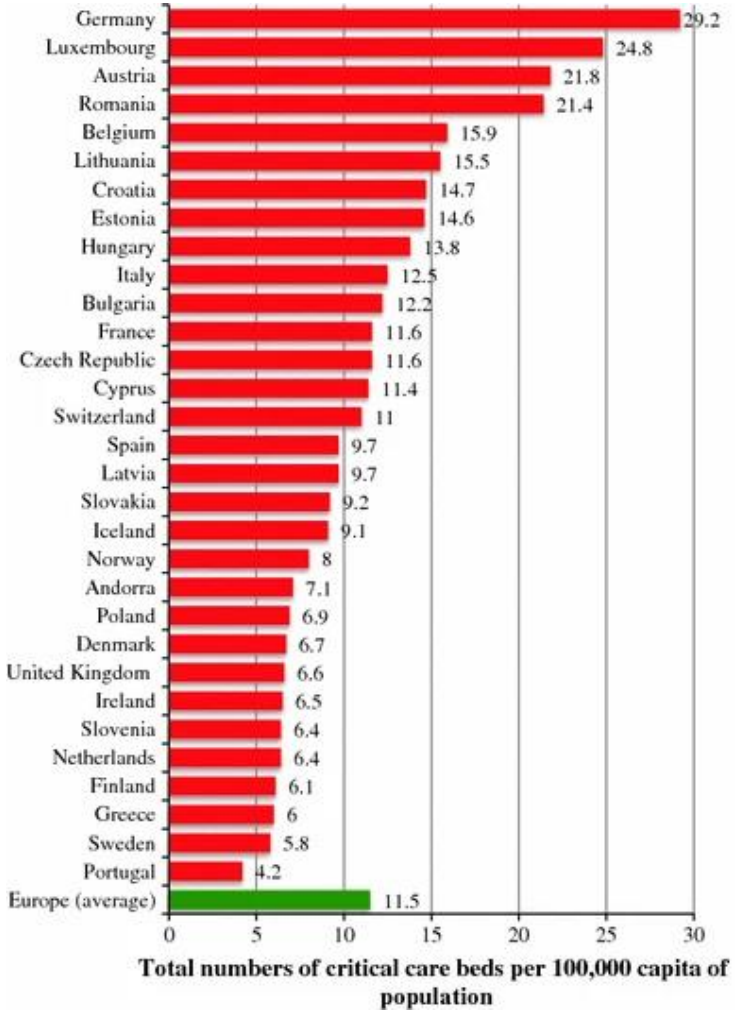
unpublished

Human to human transmission
Basic Reproduction R0

Why is R0 hard to predict?

1. Characteristics of the pathogen (how infectious?, how long infectious?)
2. Social contacts and structure of social network?
3. Seasonality
    - Germicidal effects of radiation
    - Changes in human social behavior
    - Immune response
4. Human behavior change
    - News and rumors
    - Psychological reactance

How performant is national health care?



Other factors:

- General bed capabilities
- Healthcare workers
- Number doctors
- Access to healthcare
- …

Béraud et al. (2012)

How severe is it?

https://www.youtube.com/watch?v=WQsLvvEdyOk

Dependencies:

- Capabilities of national health care
- Prevalence over **time** and space
- Resilience of population (e.g. age structure etc.)

Misperception 2

Expertenpapier zu Corona: „100.000 zusätzliche Tote“ sind möglich (Kurier April 2020)

Errors:

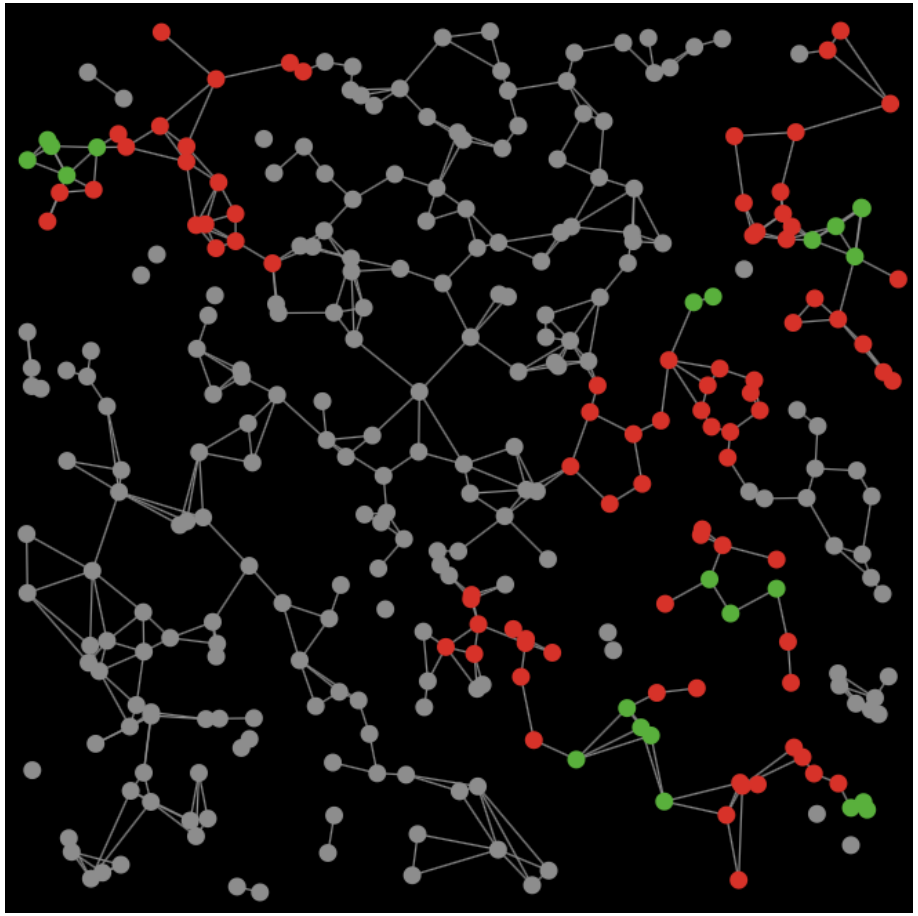
- Too high R0 and/or too high IFR
- Assumed complete ignorance of population
- Too long forecast period
- The attempt to forecast under extreme uncertainty

See more realistic but still vague estimates by The Economist.

Why and how to use models under extreme uncertainty?

1. Models to explore instead of models to predict and qualitative instead of quantitative conclusions
2. Data space exploration to reveal behavior that remains unchanged irrespective of parameter variations
3. Models to make generic instead of explicit recommendations
4. Clear communication of model assumptions and model purpose

SIR Network model in NetLogo



Download:
https://github.com/simsynser/IntroEpiMod

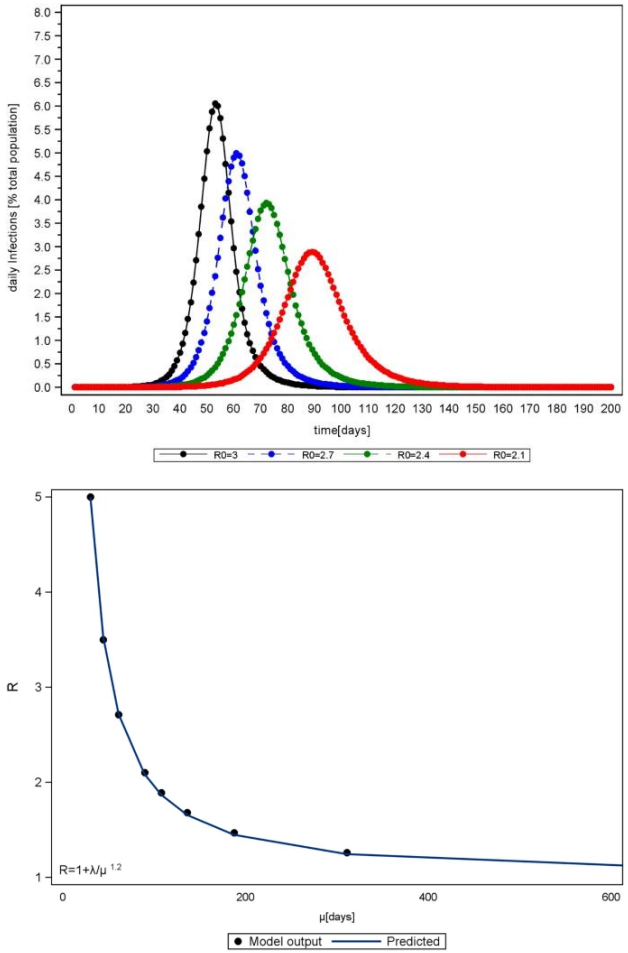
Some limitations

- Infectiousness during infectious period is not constant
- Maybe no long-term immunity and recovered may be only semi-resistant / temporarily resistant
- …

- Others?

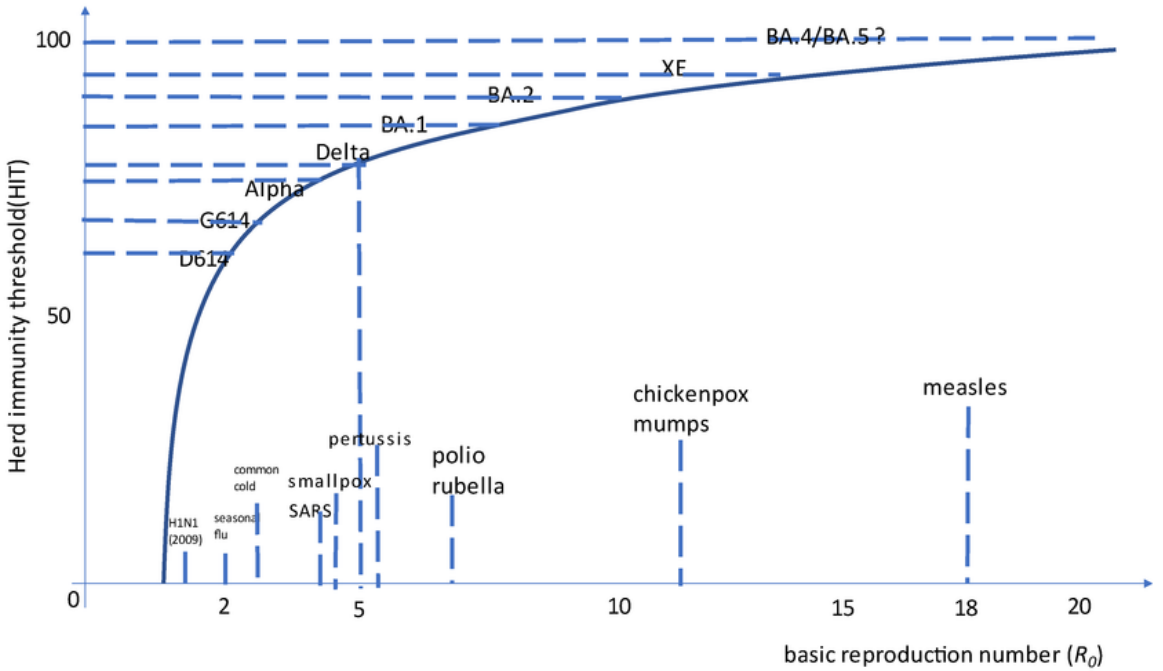
Conclusions of modeling

Curve Flattening Effect



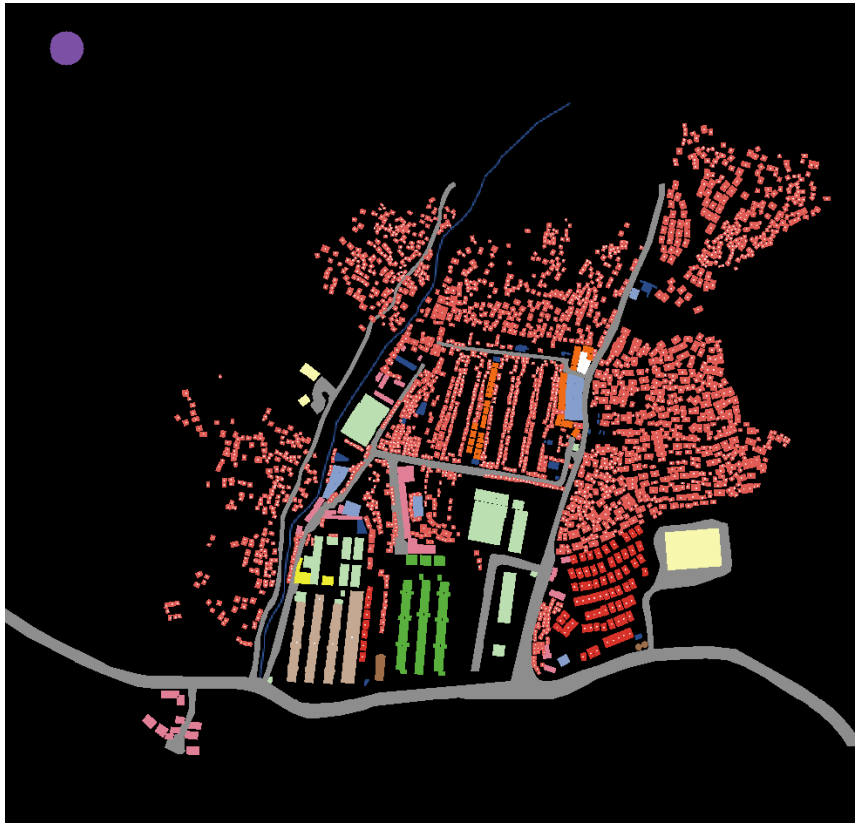
Neuwirth, Gruber & Murphy (2020)

R0 and herd immunity threshold



Focosi & Maggi (2022)

Geosimulation in NetLogo



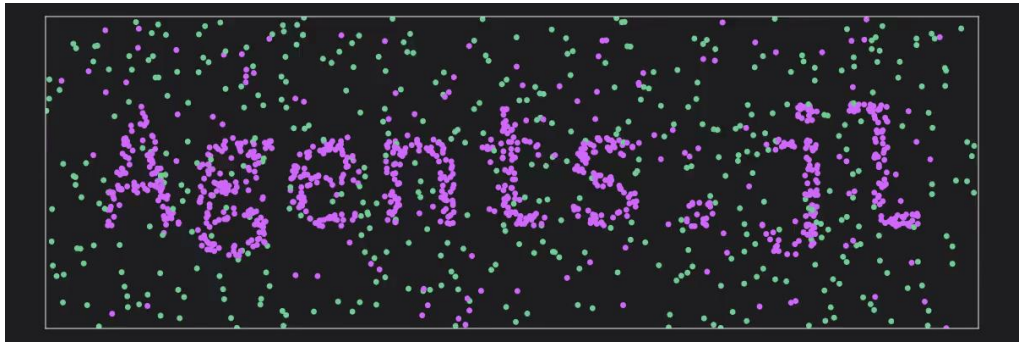
[EPA-EFE/DIMITRIS TOSIDIS]

Shyaam Ramkumar, Woi Sok Oh (2021, March 18). "AIforGoodSimulator - Modeling Covid-19 Spread and Potential Interventions in Refugee Camps" (Version 1.0.0). CoMSES Computational Model Library. Retrieved from: https://www.comses.net/codebases/89291e65-f4fc-4adc-8654-b4fc5163128a/releases/1.0.0/

Some limitations

1. Household characteristics are drawn from UN statistics on national household size and composition
2. High degree of freedom in calculation of refugee's probability of obeying interventions (in the model nationality is the key factor)
3. In general, high degree of freedom in the model implies a cumulation of uncertainties
4. Software limitation: Setup is slow and makes system analysis kind of awkward.

A possible alternative



Conclusions

- Model is designed to evaluate different strategies combined or individually
    - Wearing facemasks
    - Lockdown
    - Isolation of infected and symptomatic individuals
    - Resources usage to detect and isolate symptomatic individuals

Model is in a too early stage (e.g. evaluation of empirical inputs) to draw solid conclusions on the efficiently of respective strategies!

Literature

Béraud, G. *et al.* The French connection: the first large population-based contact survey in France relevant for the spread of infectious diseases. *PLoS One* **10**, e0133203 (2015).

Focosi D, Maggi F. Recombination in Coronaviruses, with a Focus on SARS-CoV-2. *Viruses*. 2022; 14(6):1239. https://doi.org/10.3390/v14061239

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