FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
FACULTY OF ENGINEERING

Two simulation models for COVID-19 epidemic dynamics and some related aspects

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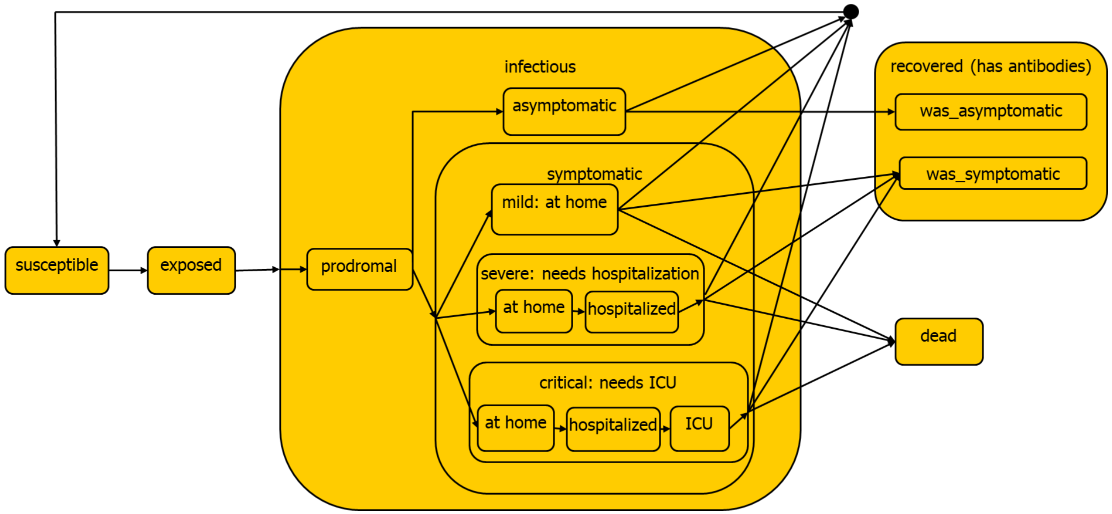
- Extended SEIR Model (System Dynamics)
- Agent-Based Model
- Conclusions & Further Work

Updated version based on: R. German, A. Djanatliev, Lisa Maile, P. Bazan, H. Hackstein: Modeling Exit Strategies from COVID-19 Lockdown with a Focus on Antibody Tests, Preprint, MedRxiv, April 2020, doi: https://doi.org/10.1101/2020.04.14.20063750.

Extended SEIR Model

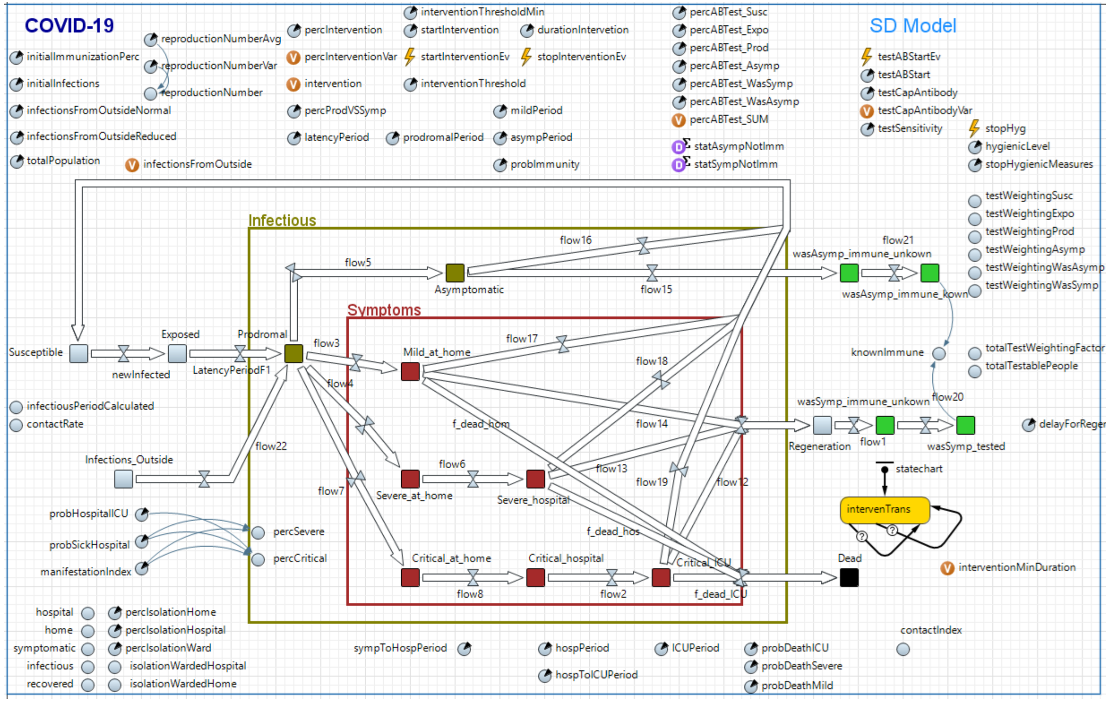
Formulated as System Dynamics/ODE/Compartment Model*



- counts persons in health states and transitions between them, e.g., by infection, recovery, etc.
- allows to model
    - disease dynamics
    - interventions: isolation, hygienic measures, adaptive repetitive lockdowns, AB tests (with sensitivity)
- solution
    - just ODE solver
    - very sensitive to parameters (e.g., infectious period)

* all equations are given in the paper

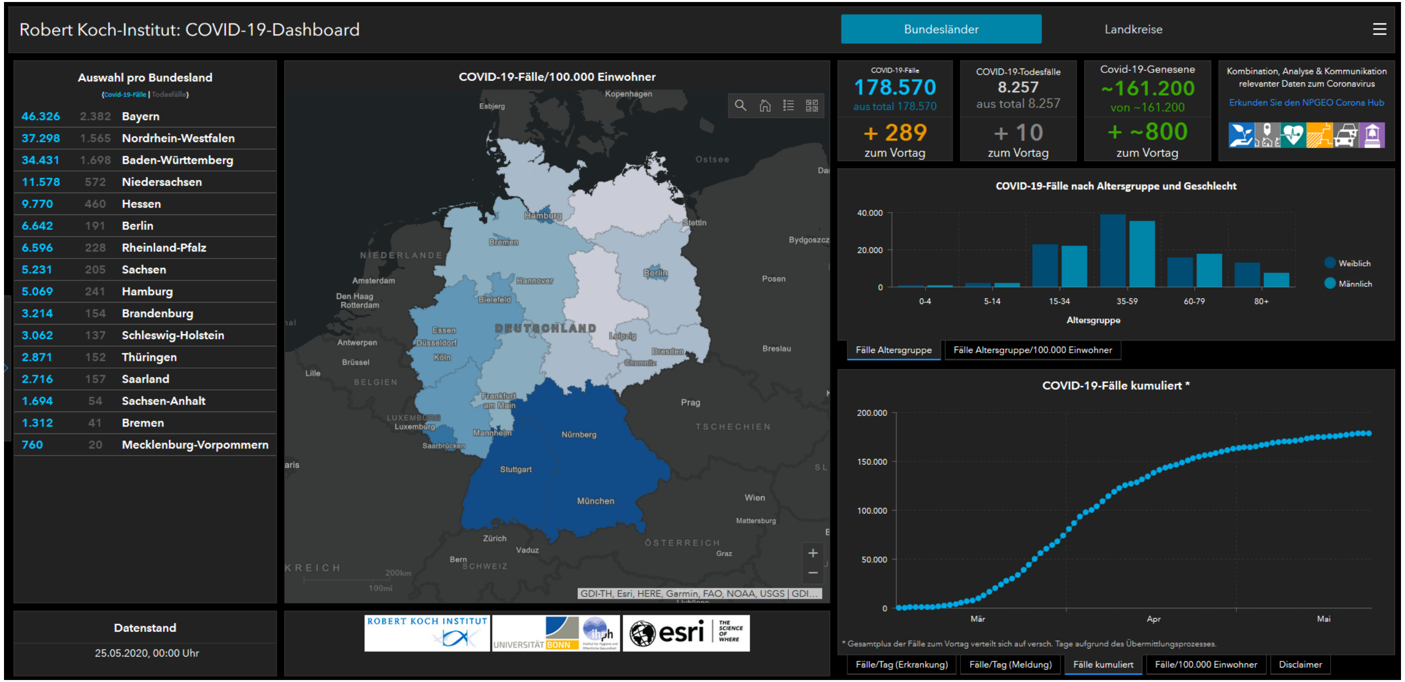
Realization:



with simulation software AnyLogic, www.anylogic.com

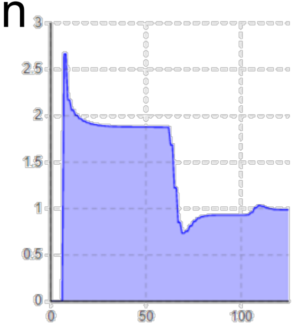
Fit the Parameters

https://experience.arcgis.com/experience/478220a4c454480e823b17327b2bf1d4



Fit the Parameters

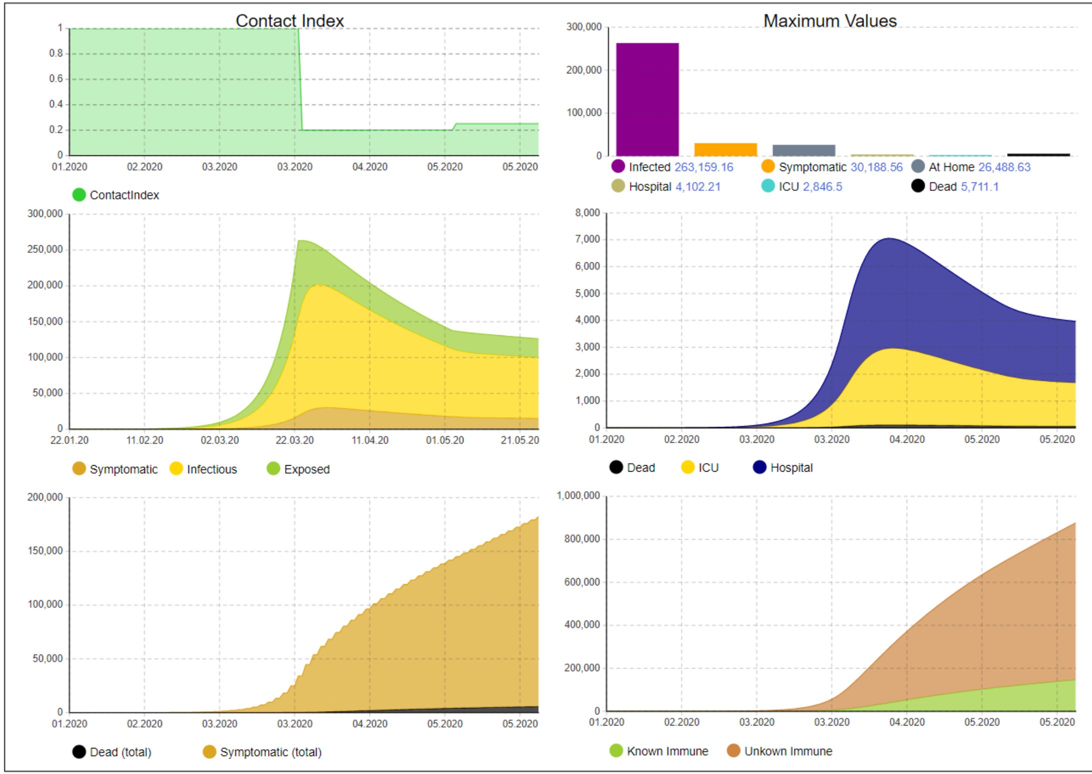
Lockdown starting on Monday 23.03.2020



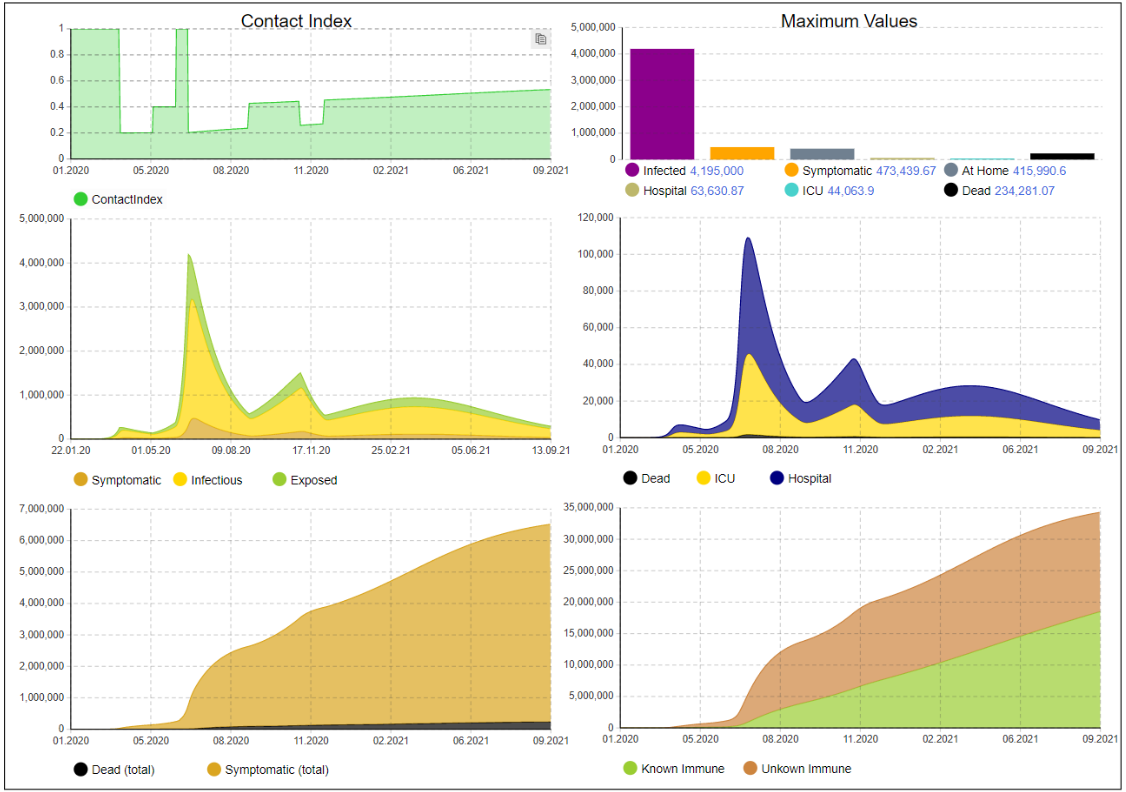
Screenshot: 25.05.2020

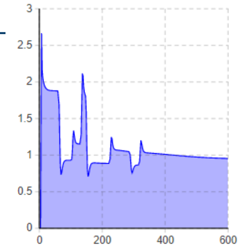
Assuming that RKI only captures symptomatic cases -> model maps real data

large number of unkown cases



Repetitive Lockdowns with AB Tests

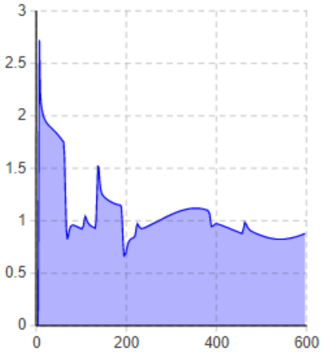


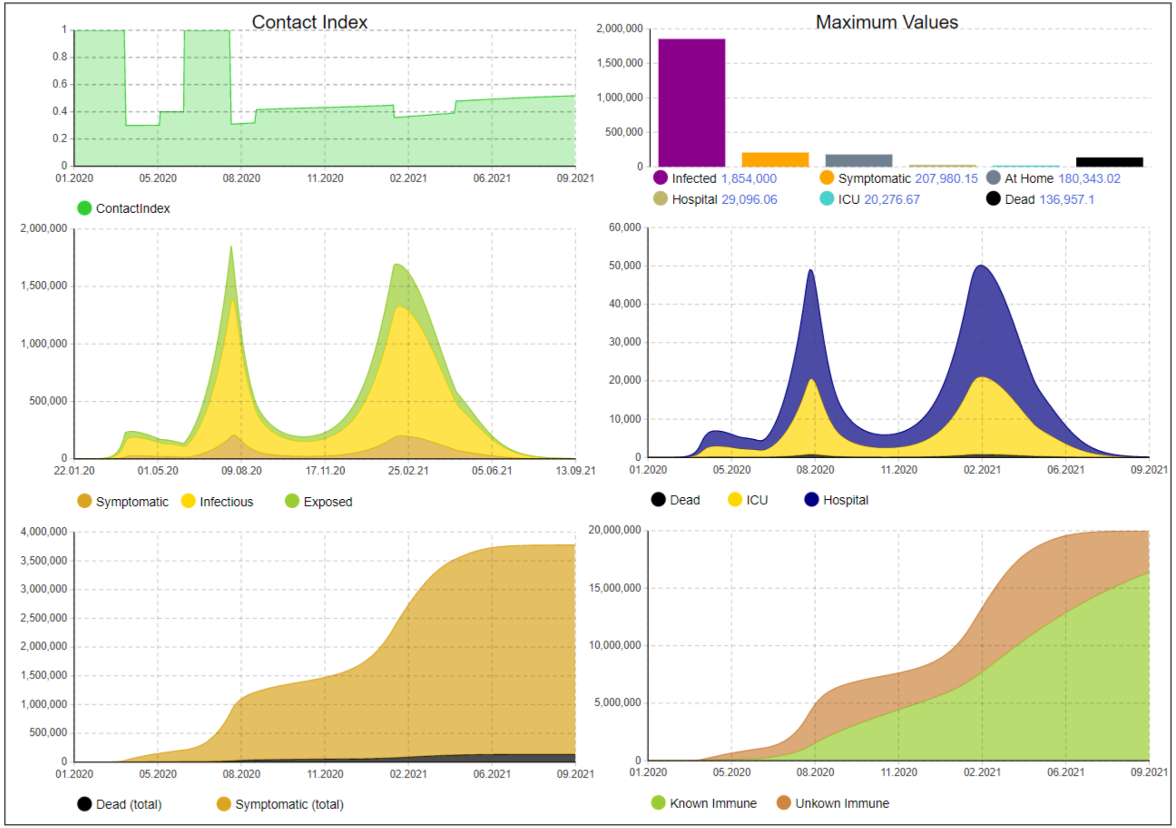


- 2020/06/1
  - test capacity 100.000/day
  - remove hygienic measures
- assume immunity if AB test is positive
- assume that symptomatics get ABs and will get immune
- apply tests randomly on others
- ca. 4.5 millions **additionally** excluded from last intervention
- up to ca. 12 millions with improved testing strategies

Seasonality

- second peak in winter 2021
- ca. 5.5 millions **additionally** excluded from last intervention

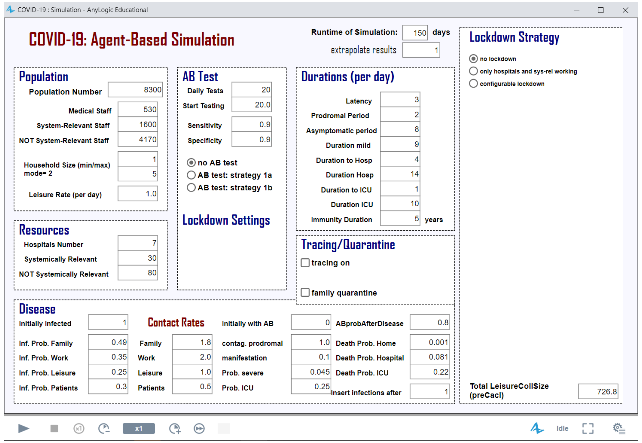




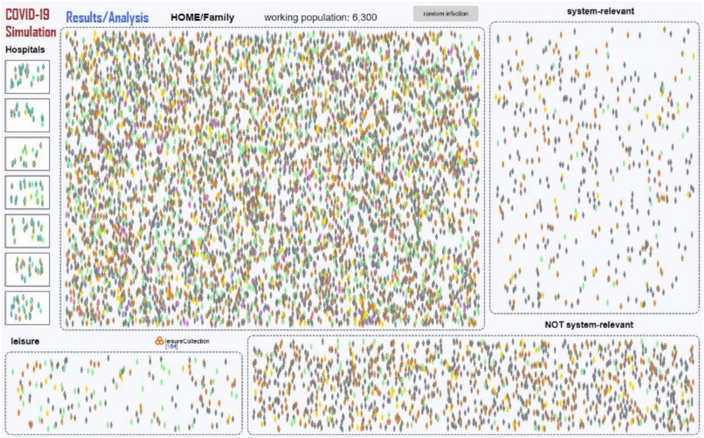
Agent-Based Model

- individuals with health states, contacts, and infections
- in family, leisure, work, hospitals
- configuration of interventions

Configuration dashboard:



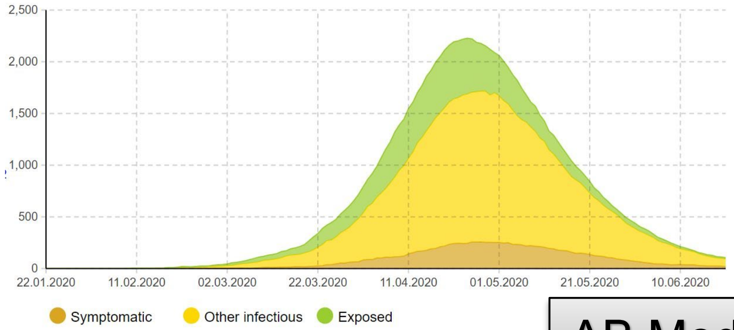
Animation:

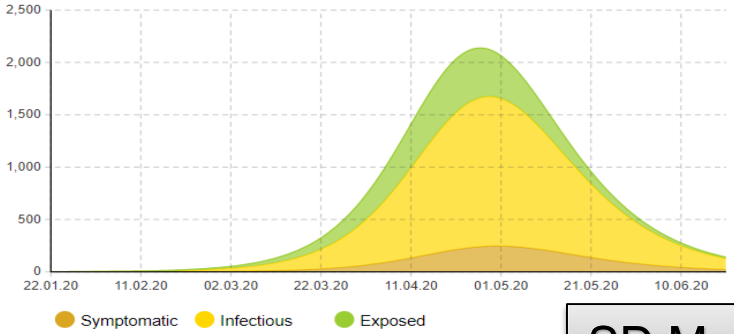


with simulation software AnyLogic, www.anylogic.com

Agent-Based vs. System Dynamics Model

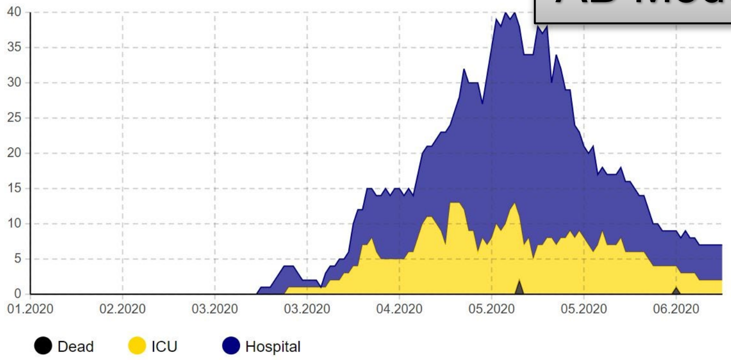
Calibration: all agents in leisure, match contact rates and infection probabilities

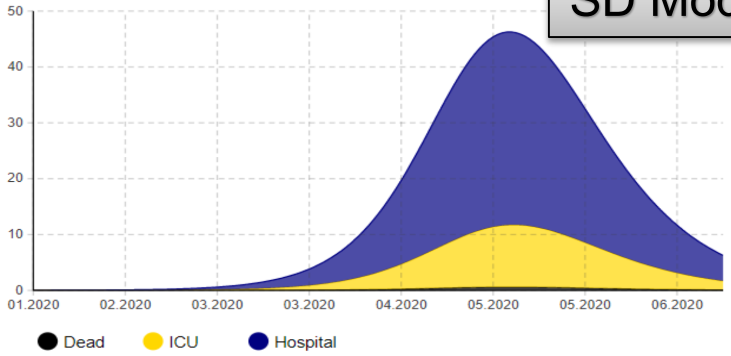




AB Model

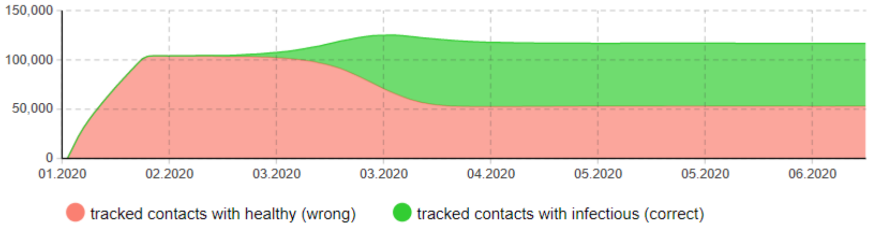
SD Model





Digital Tracing

- digital contact tracing instead of traditional manual tracing scales to population size and gives signals instantaneously
- it thus promises to control an epidemic without lockdown
- tradeoff between privacy issues, health benefits, and social effects
- in agent-based model: every agents records its contacts of the recent period (e.g., 14 days)
- results: suppression of disease, number of false alarms (= unnecessary quarantines), etc.
- first example results (not yet credible):



Family Sizes 2.67

Quarantine error ratio (tracing): 0.72

Conclusions & Further Work

- System dynamics model
  - can be extended in many ways
  - e.g., PCR tests, relaxation of implicit exponential assumption, sub-populations, sensitivity and specifity of all tests, …
  - however, there seems to be a modeling limit in complexity and consistency (not for the solution)
- Agent-based model
  - can better include such extensions
  - e.g., can show effects of digital tracing
  - but parameterization more challenging
- Open to collaboration
  - medical/virological/epidemiological expertise, data, parametrization
  - methodology for parametrizing agent-based model
  - generalization of SD model to integral equations to better model timing effects

Appendix

Parameters

Population

totalPopulation:	83000000
initialInfections:	1
initialImmunizationPerc:	0
infectionsFromOutsideNormal:	2
infectionsFromOutsideReduced:	1

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Reproduction

reproductionNumberAvg:	1.7 // 2.3
reproductionNumberVar:	0.7

Paste from clipboard

Duration/Periods

latencyPeriod:	3
prodromalPeriod:	2
percProdVSSymp:	1.1
asympPeriod:	9
mildPeriod:	9
sympToHospPeriod:	4
hospPeriod:	10
ICUPeriod:	10
hospToICUPeriod:	1
delayForRegeneration:	4

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Illness/Death Probabilties

probHospitalICU:	0.75//0.333
manifestationIndex:	0.1666
probSickHospital:	0.14
probDeathICU:	0.28
probDeathSevere:	0.081
probDeathMild:	0.001
probImmunity:	1

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Antibody Tests

testCapAntibody:	100000
testABStart:	132
testSensitivity:	0.95
percABTest_Prod:	0.2
percABTest_Susc:	0.05
percABTest_Expo:	0.2
percABTest_WasSymp:	0.0000000001
percABTest_Asymp:	0.2
percABTest_WasAsymp:	1-(this.percABTest_Sus

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Intervention/Isolation

percIntervention:	0.7
startIntervention:	61
durationIntervetion:	41
interventionThreshold:	16500
interventionThresholdMin:	9500
percIsolationHospital:	0.95
percIsolationHome:	0.8
percIsolationWard:	0
hygienicLevel:	0.6
stopHygienicMeasures:	131

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