From agent-based scenario simulations of disease dynamics to expert support on public health interventions

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Oral abstract presentation

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Thanks to project collaborators / paper

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Harnessing multi-output machine learning approach and dynamical observables from network structure to optimize COVID-19 intervention strategies

Caroline Alves, Katharina Kuhnert, Francisco Aparecido Rodrigues, Michael Moeckel

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State of art @ Covid-19: Scenario based disease modeling

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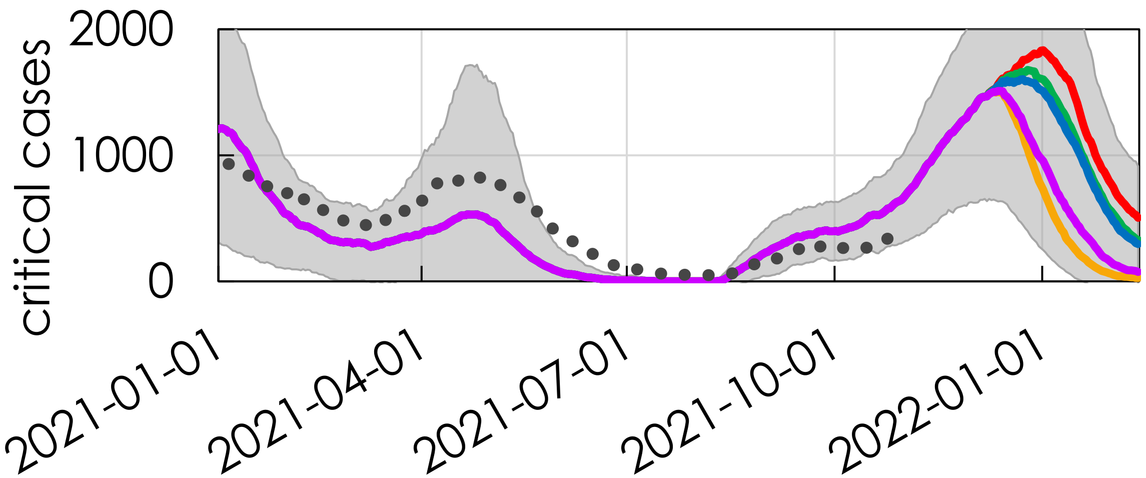
- Tools were made to predict disease dynamics
- Scenario techniques used to probe possible future developments and the effects of public health interventions



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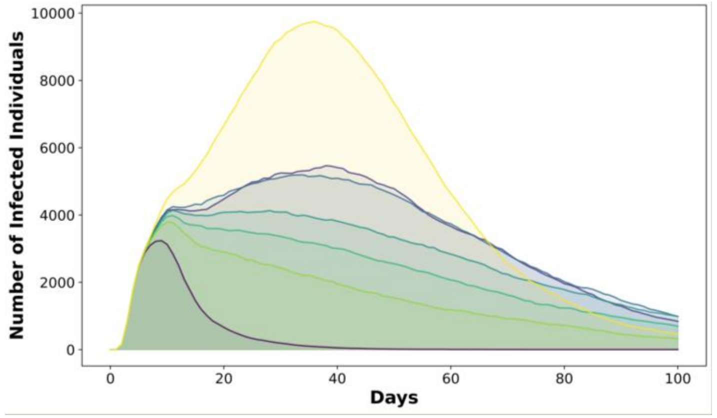
- Comparisons between different interventions difficult

Key message of the talk:
Actual question is different!

From:

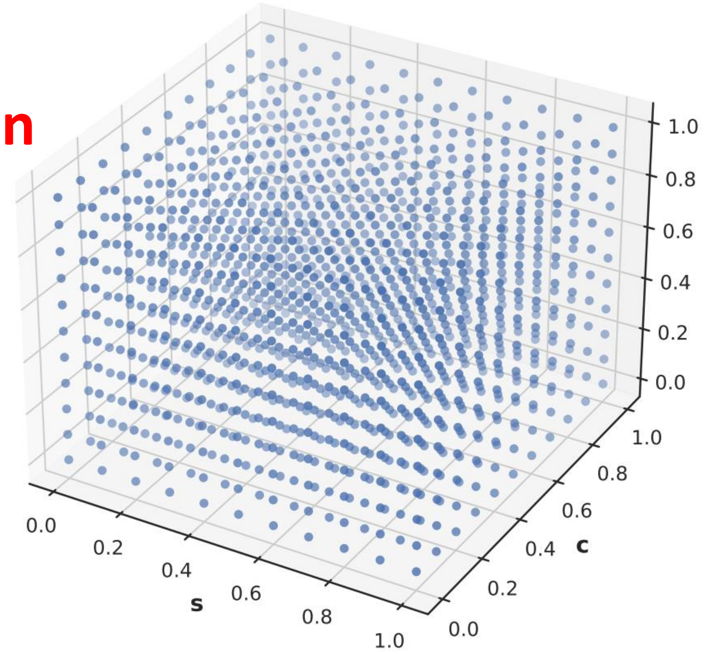
Prediction of disease dynamics



Development of efficient methods

To:

Representation of equivalent options for public health interventions



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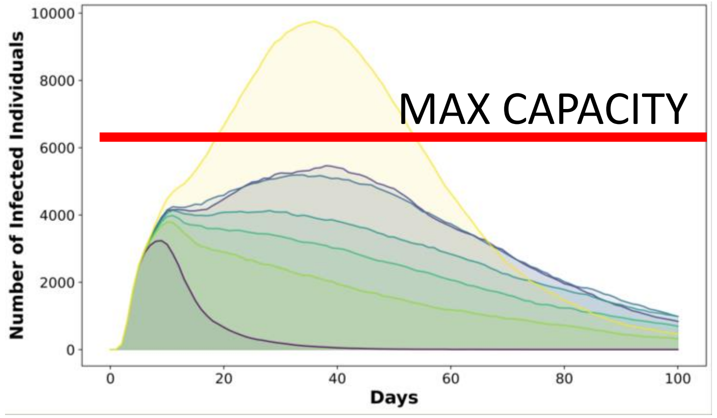

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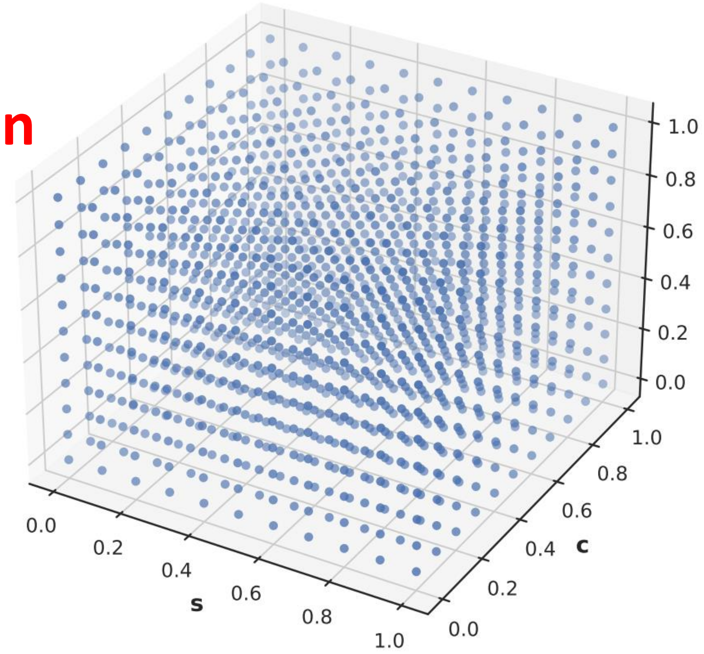

Selection of permissible dynamics w.r.t. external constraints

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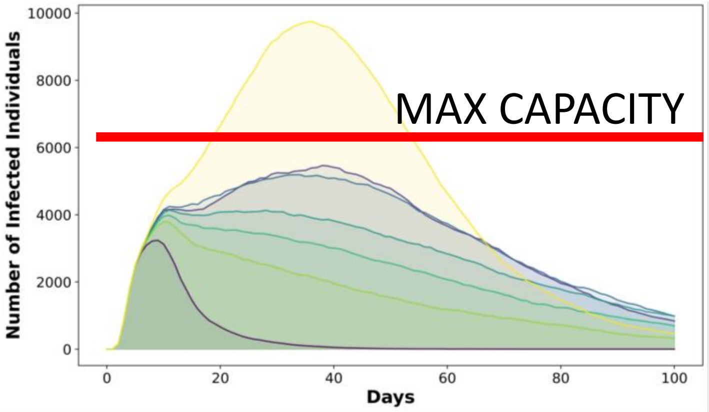

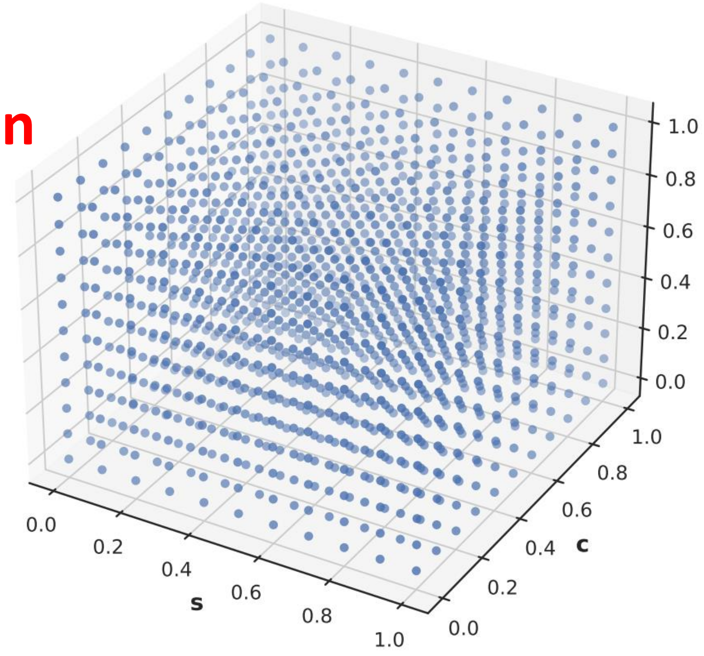

Inverse model

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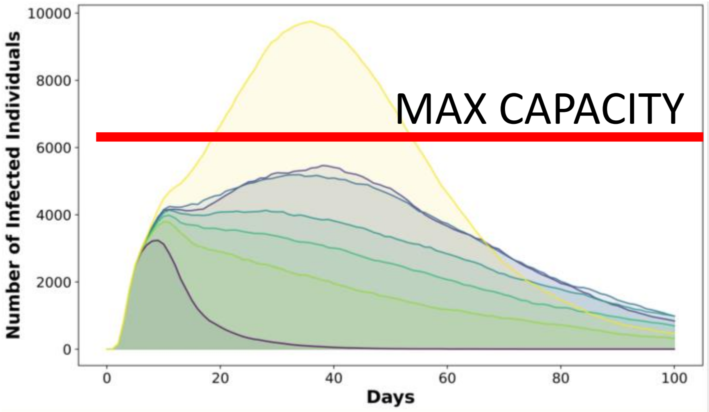
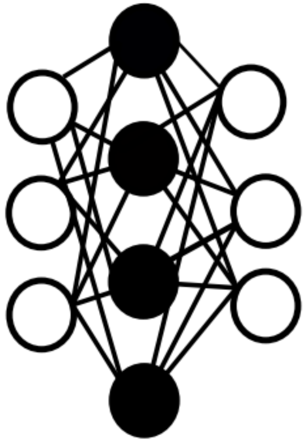
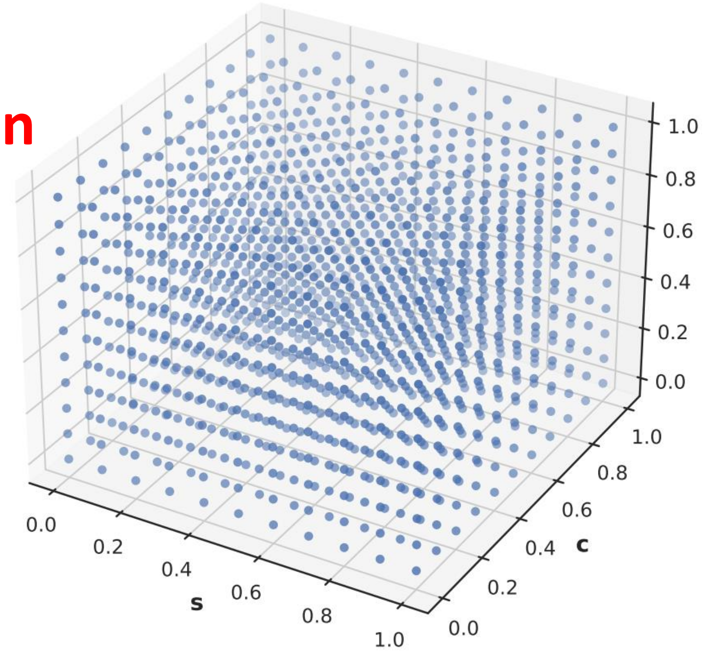


Machine Learning





Inverse model

Selection of permissible dynamics w.r.t. external constraints

Agent-based stochastic simulators: compartments & contact networks

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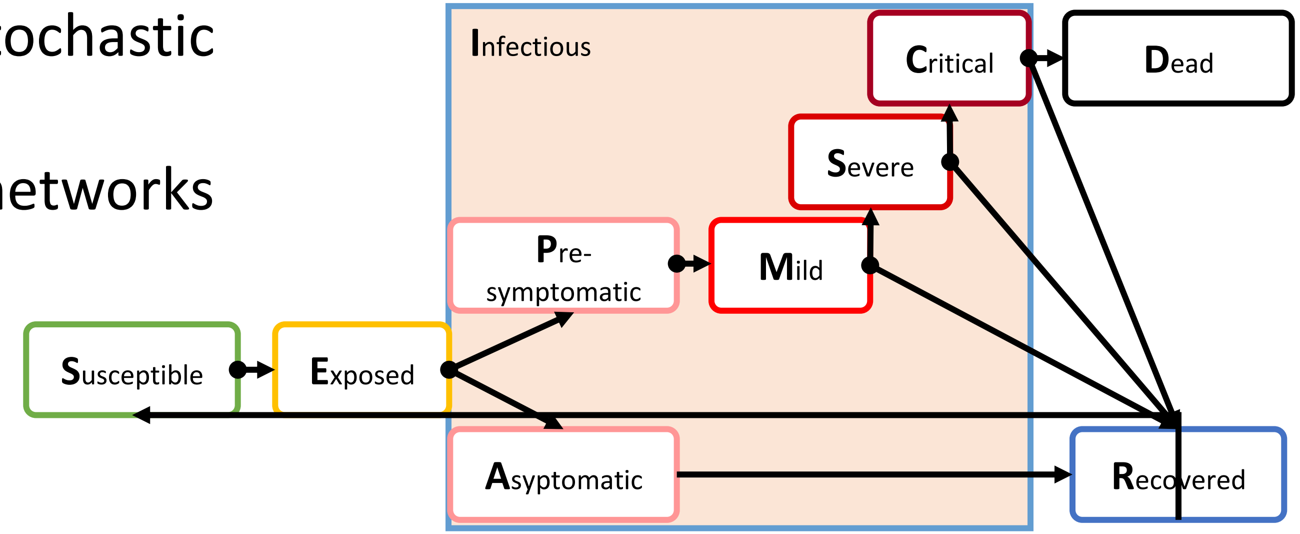
- Infectious dynamics modeled by a stochastic random process of agents
- Agents are represented on contact networks (multi-pgraph networks)



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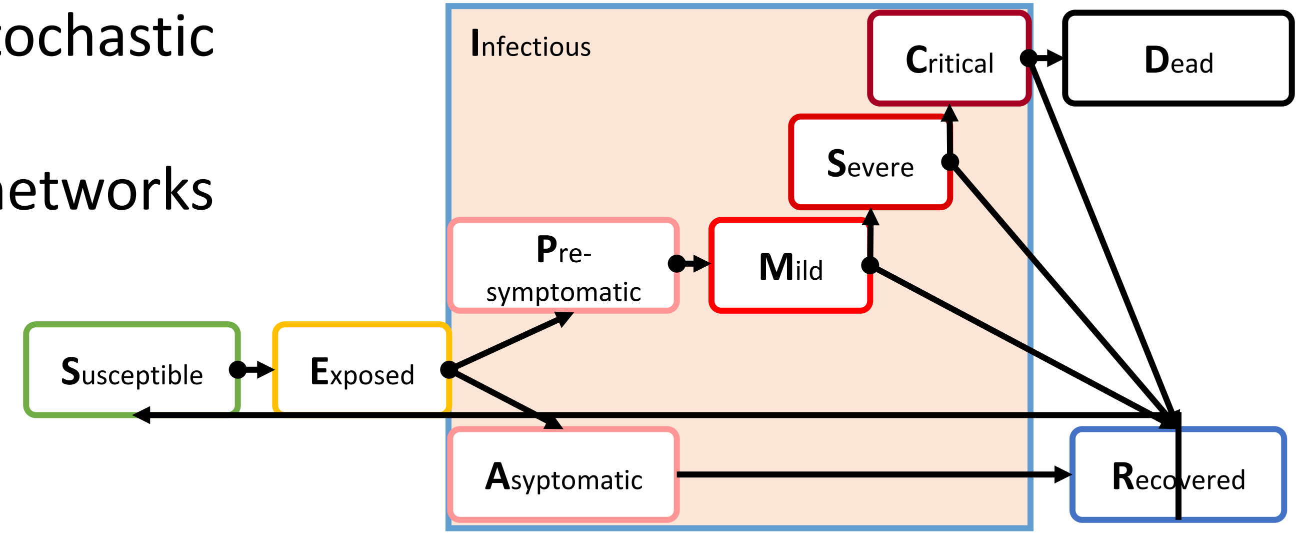

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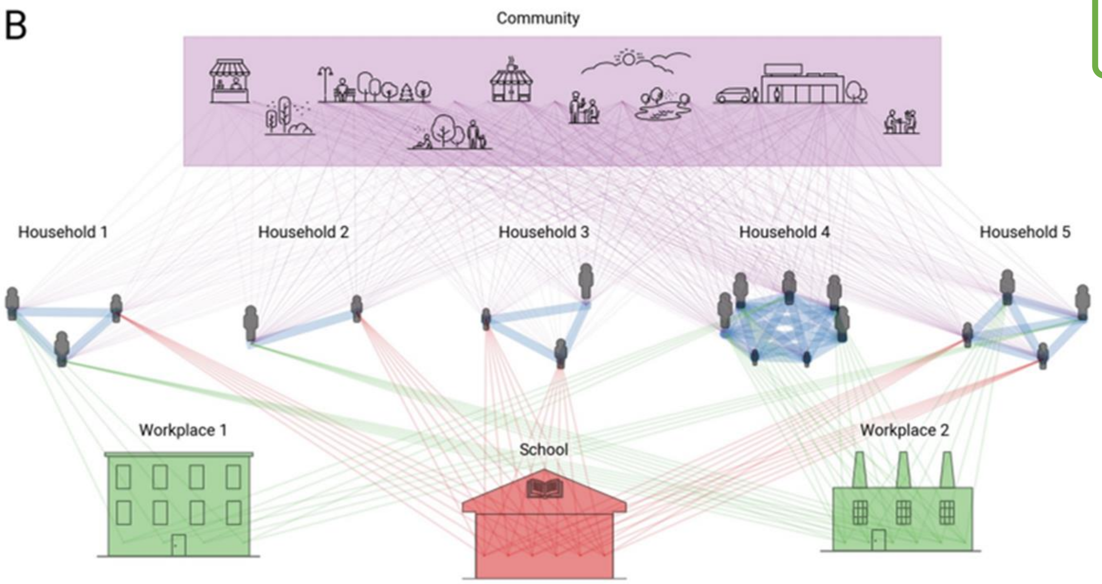

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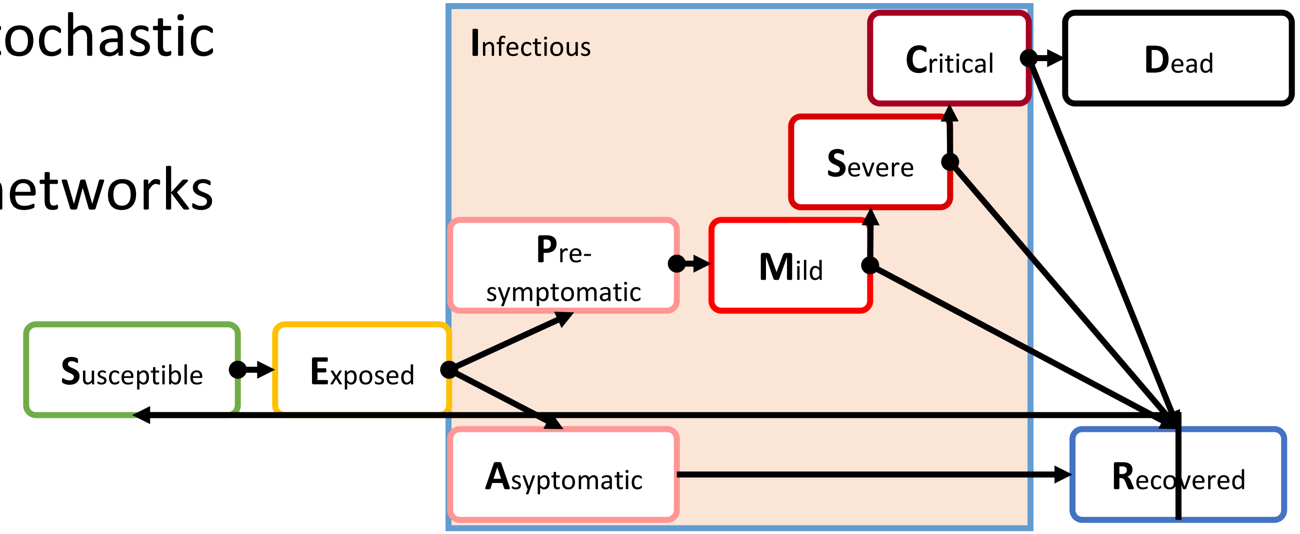

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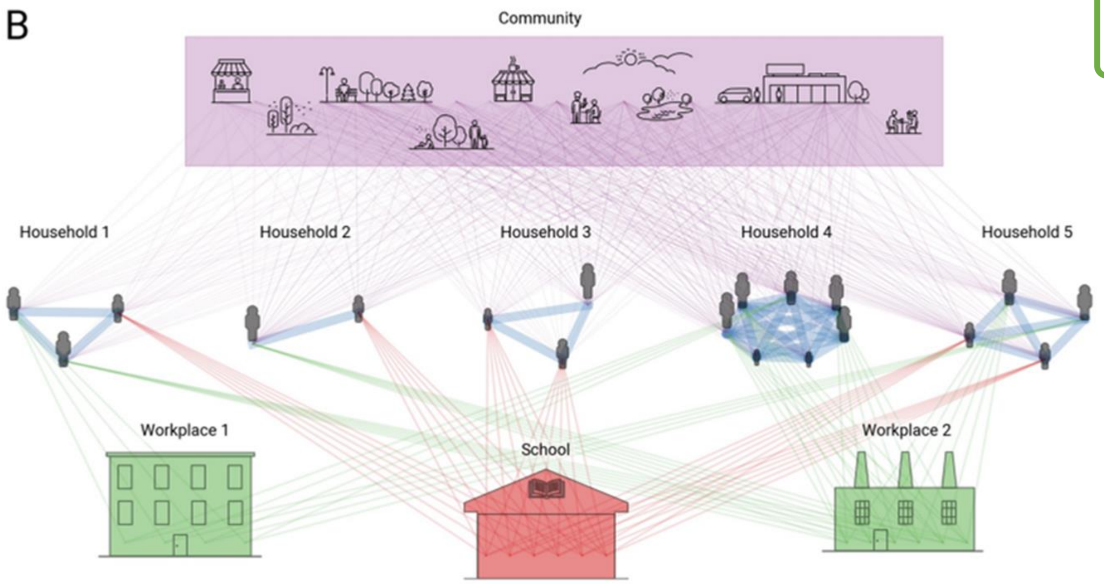

https://doi.org/10.1371/journal.pcbi.1009149

Multi-graph structure of contact networks
Home, school, work, community

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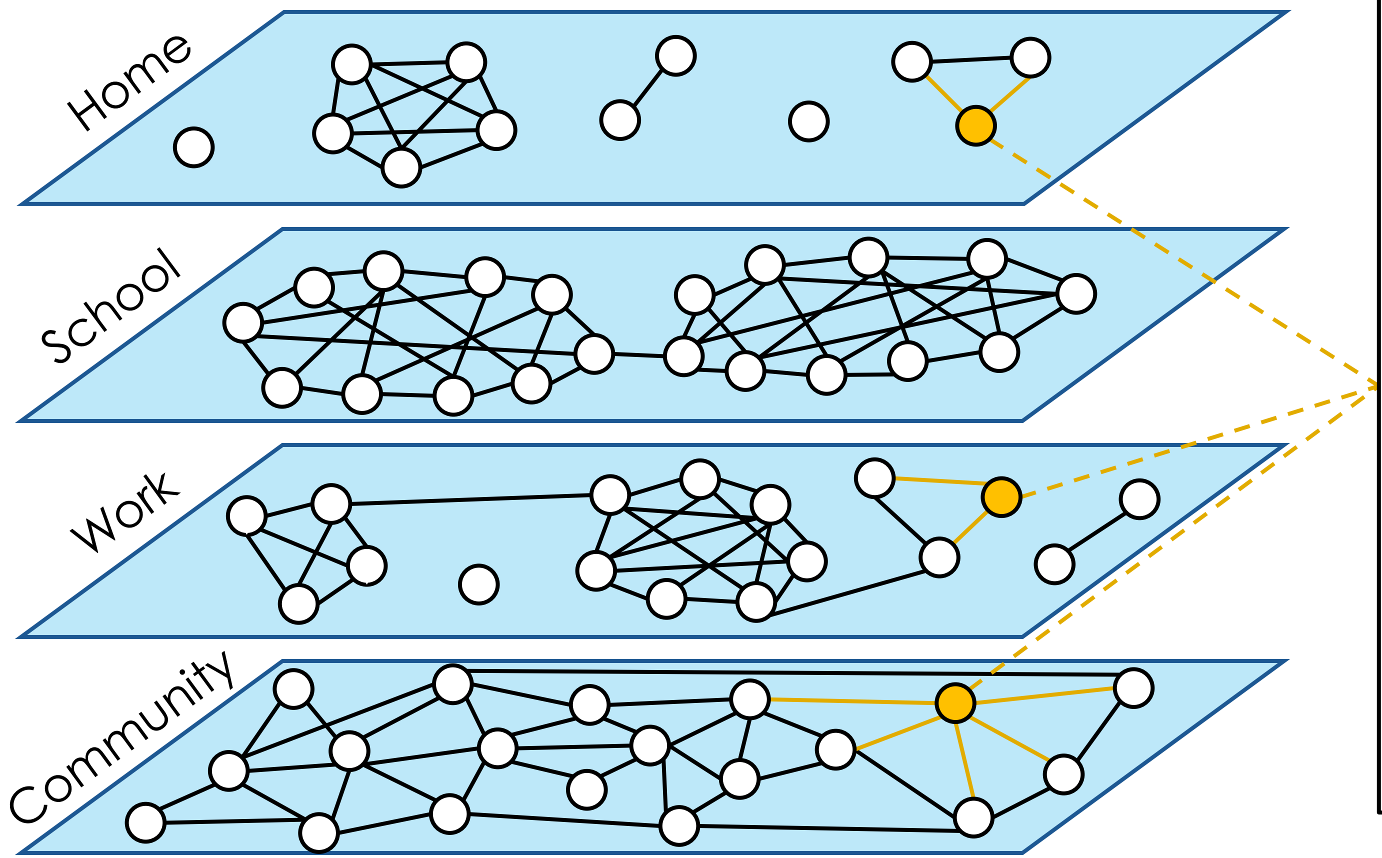
Contact layers:



Agent State:

ID	19573
age	46
sex	male
contacts	{h: […], s: […],…}
infectious	False
…	
severe_prob	0.049
death_prob	0.273
…	
date_infected	‘2020-10-12‘
date_recovered	‘2020-10-26‘
date_vaccinated	‘2021-05-05‘
…	

Numerical complexity: Multi-graph problem for all configurations

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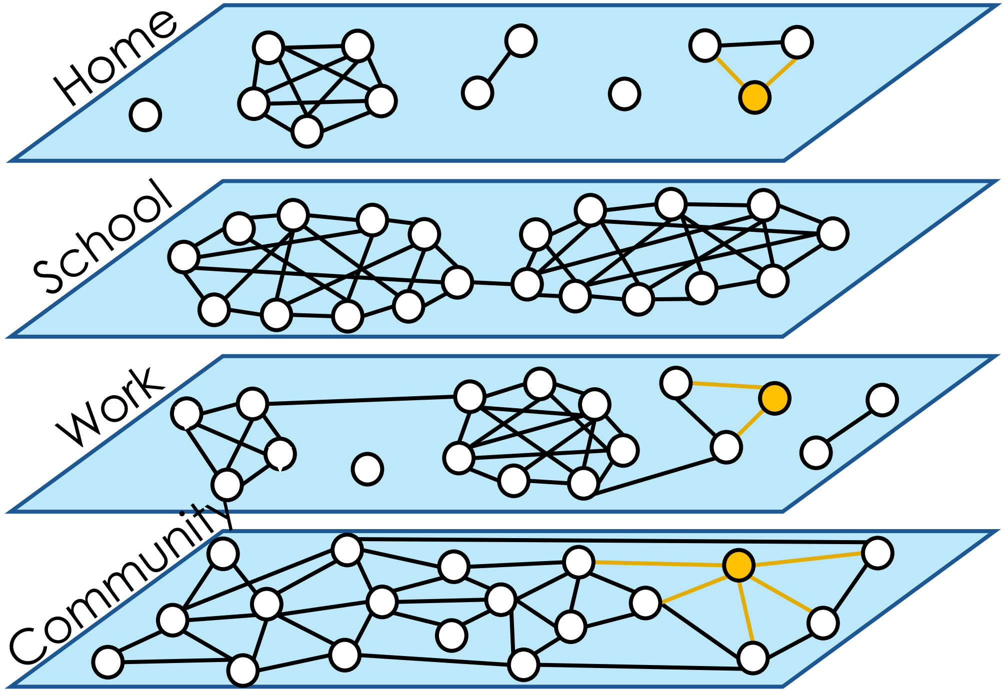
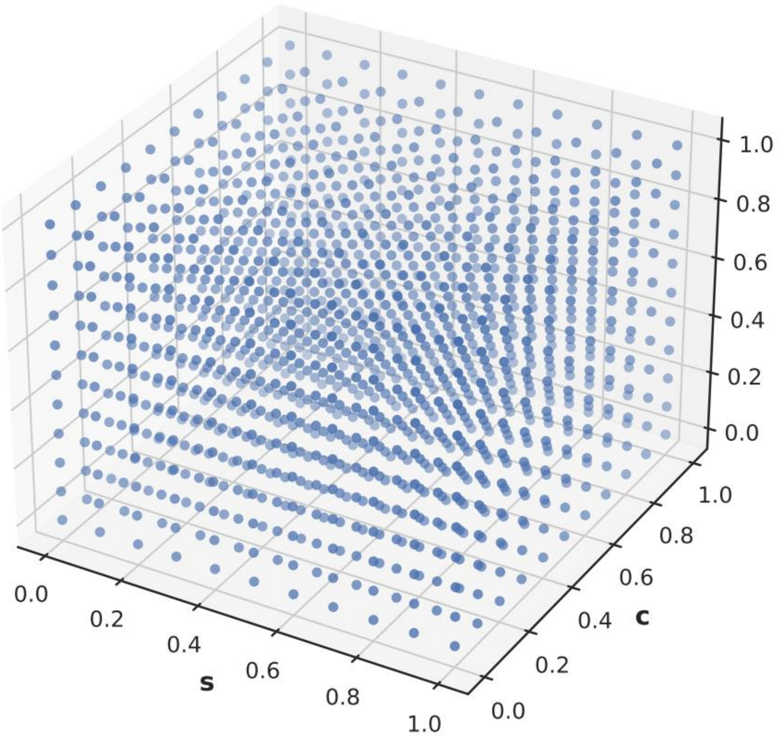
Contact network subgraphs represented by a adjacency matrix



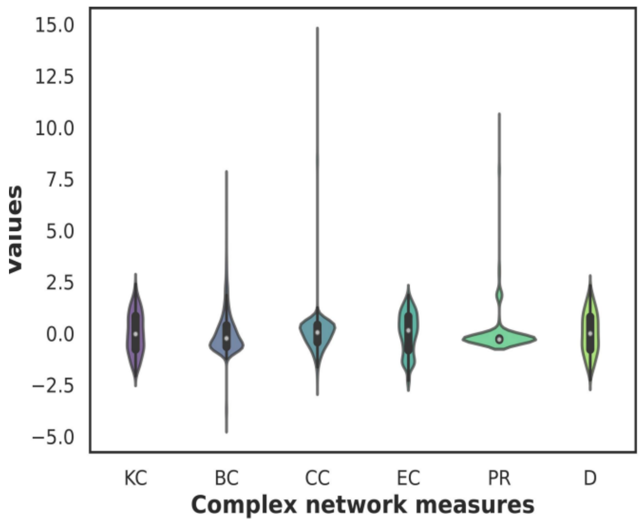
Interventions (contact restrictions) change contact networks:

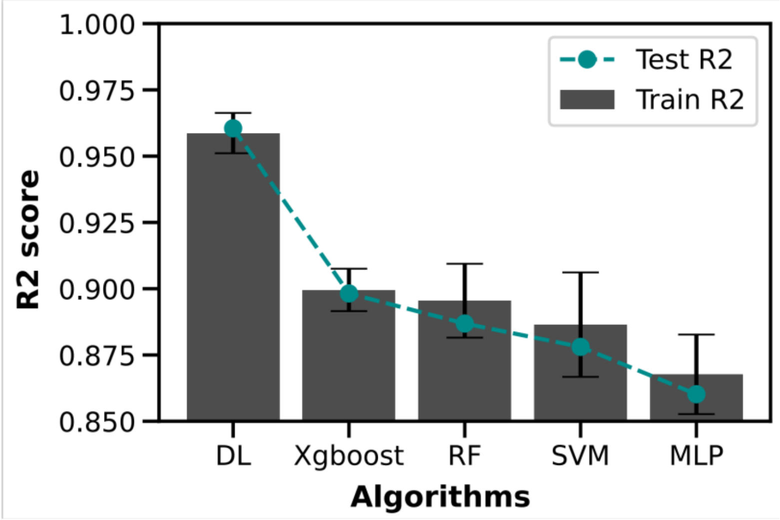


Numerical complexity
Simplifications needed

Reduced (sufficient) network characterisation by complex network measures

- Create synthetic dataset from COVASIM runs
- Extract complex network measures from adjacency matrix
- Their values differ depending on chosen restrictions





- They have predictive power on the disease dynamics
- Shown empirically by testing various machine learning models (deep learning performs best, >1000 simulation runs used)

1st result: complex network measures are a helpful simplification for contact modeling

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- Contact restrictions imposed by public health interventions modify contact networks
- Global interventions (e.g. by public orders) change the contact network in a global way which is captured by modified values of complex network measures

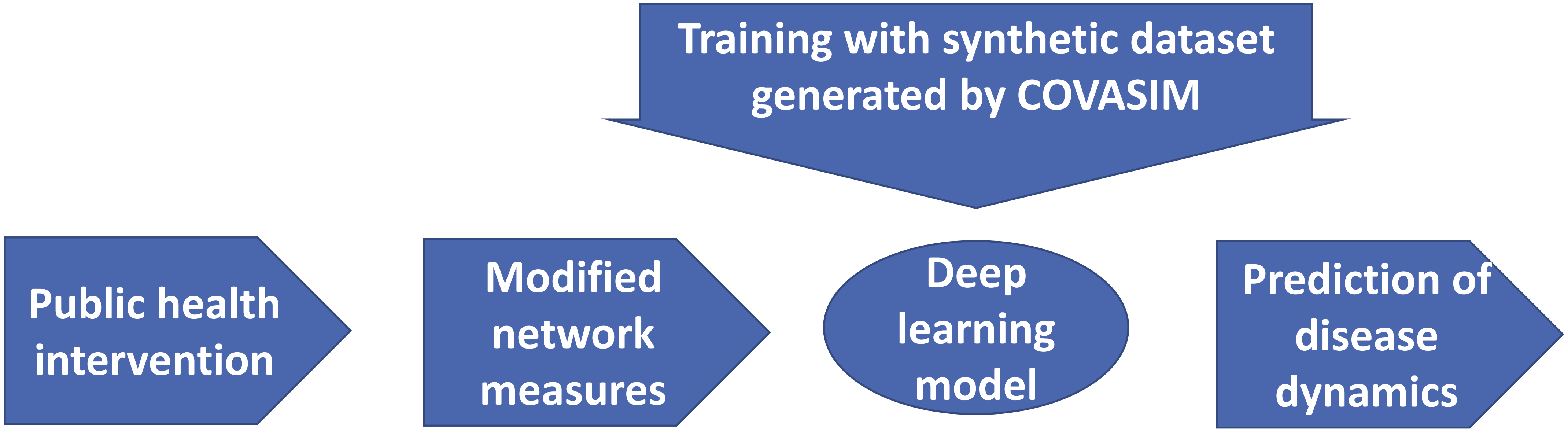
Public health intervention → **Modified adjacency matrix** → **Modified network measures** → **Prediction of disease dynamics**

Set-up through COVASIM initialization

Deep Learning model

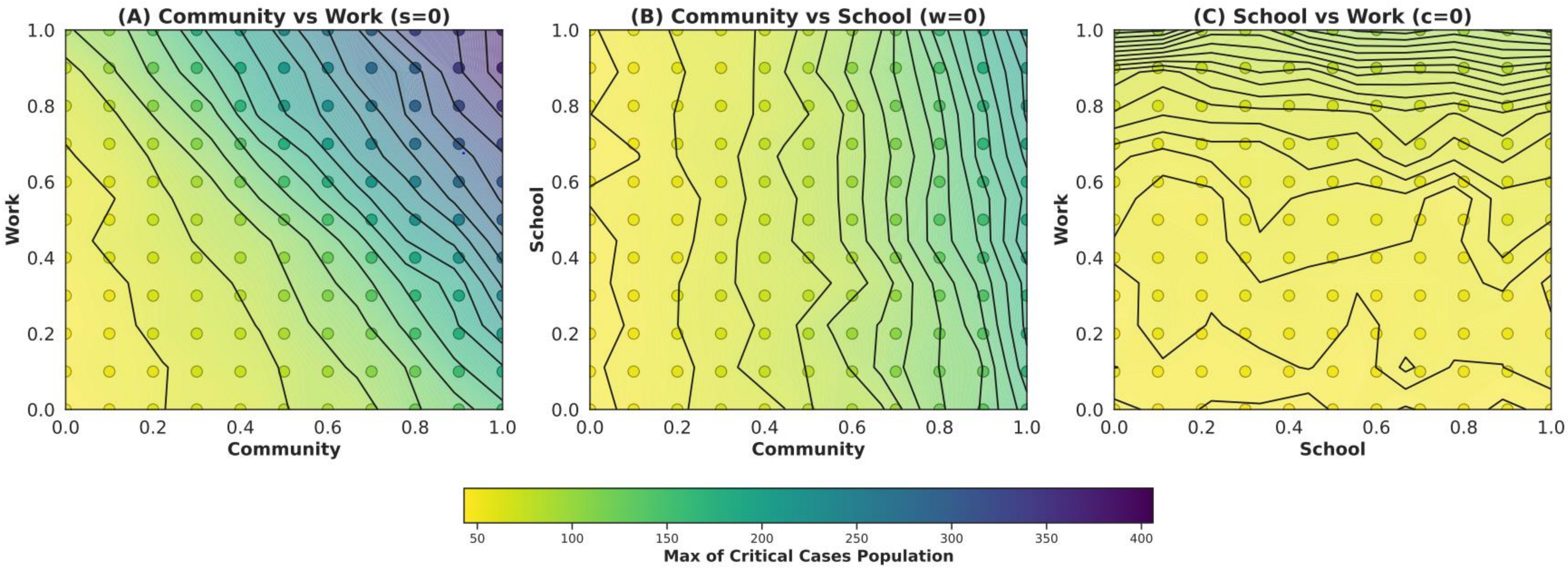
Speed-up of phase space scanning

- Machine learning methods are powerful tools for interpolation
- Training a substitutional neural network allows for quick evaluation of further configurations



2nd result: manifold of equivalent interventions mapped out

Intersections of intervention phase space



Discussion & Outlook

Next steps:

- Extension to other public health interventions
- Improved tools for manifold representation in intervention space
- Collaborations welcome!

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