DCNAustria
Disaster Competence Network Austria
Austrian Disaster Research Days 2019
14.-15.Oktober 2019, Technische Universität Graz

Modellierung systemischer Risiken im analogen und im digitalen Zeitalter

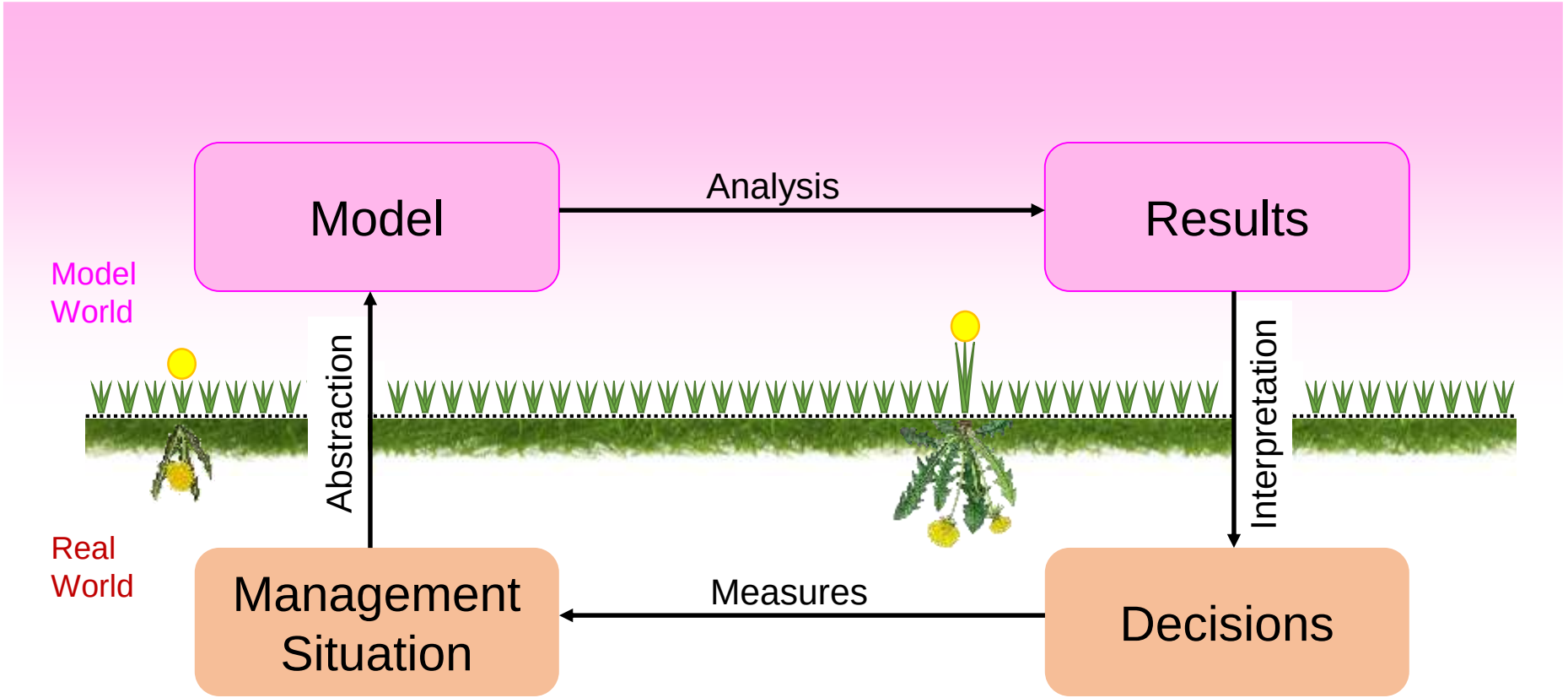
Univ. Prof. DI Dr. Siegfried Vössner
DI Dr. Dietmar Neubacher

Modellierung komplexer Risiken

Systemische Risiken – im analogen und im digitalen Zeitalter

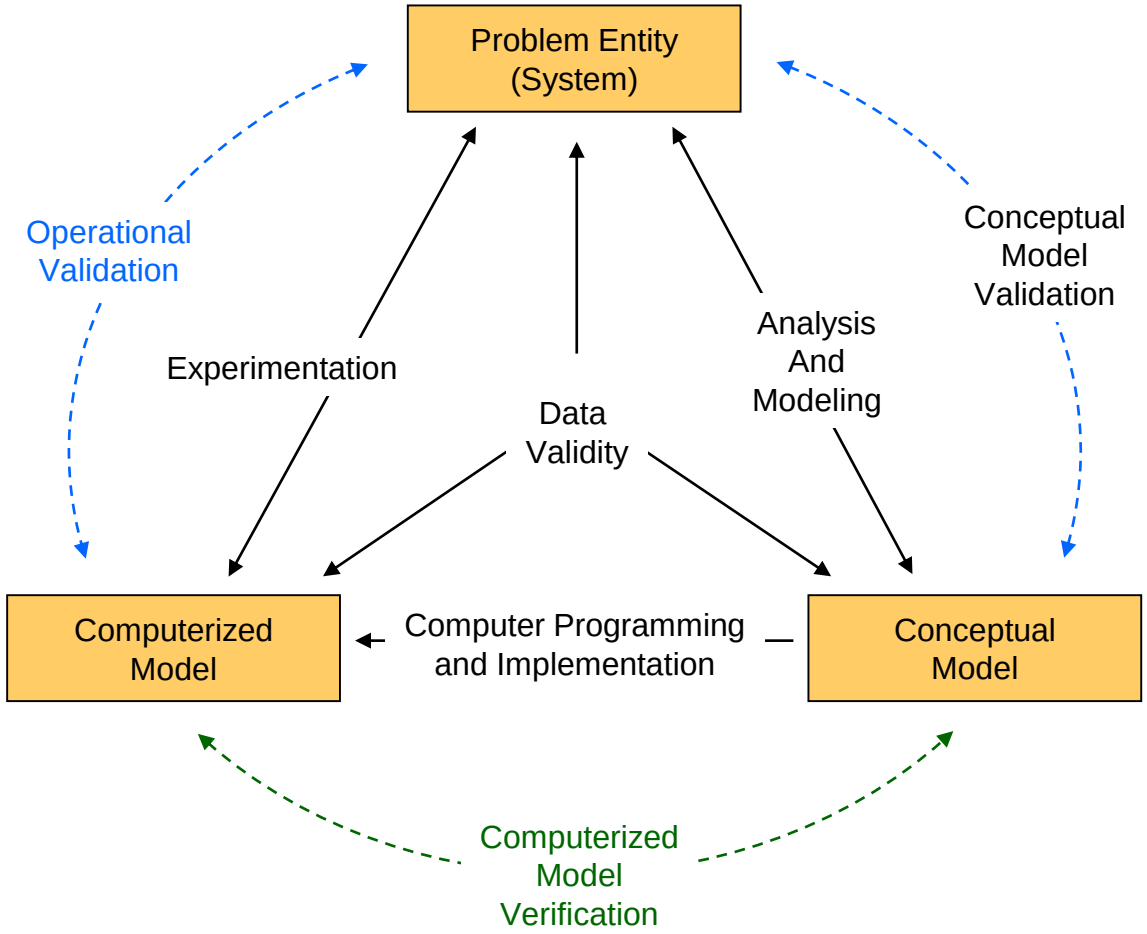
The Modeling Process – Reality and Abstraction

Modeling abstracts reality in order to provide understanding AND a testbed to experiment...



Source: inspired by J.Kalvenes

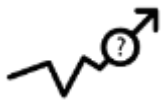
Making sure Models are „correct“ and „true“ (valid)



Source: Simplified version of the modeling process, according to Sargent (1981)

The Generalized Role of Modeling and Simulation

- M&S is used for several purposes and can be conceptualized in a tripartite architecture of input, output and mechanism, which is divided in structure and behavior.
- This structure also emphasize the “purpose-relativity” of simulation. This extends to those aspects of the structure which are taken as points of new information.

	Prediction		Explanation			Retrodiction		
	 Prediction	 Comparison	 Learning	 Optimization	 Explanation	 Evaluation	 Analysis	 Ranking & Selection
Input	✓	✓	✓	✓	?	?	?	✓
Structure	✓	✓	✓	?	?	?	✓	✓
Behavior	✓	?	?	?	?	✓	✓	✓
Output	?	?	?	✓	✓	✓	✓	✓

✓ Known information, correspondence with real world

? New information, gathered from the simulation output

Illustration idealized - Due to the purpose-relativity, many variations are possible!

The Modeling and Simulation Template

Purpose / Role	Prediction	Comparison	Optimization	Learning	Explanation	Evaluation	Analysis	Ranking & Selection
Domain Knowledge	Data Driven	Model Driven	Experts	Participation				
Problem Formulation	Cause - Effect	Feedback	Individual behavior	Queuing System	Diffusion	Stochastic	Deterministic	
Model	Representation: Physical, Mathematical	Behavior: Static, Dynamic	Problem solving: Numerical, Analytical					
Design	Single Model	Combine Models	Integrate Models	Alternate Models over time (t=0, t=n, t=n+m)				
Implementation	FlexSim	Tecnomatix Plant Simulation	Powersim Software					
Properties	Performance: Fast Execution, Real-Time	Quality: Credibility, Visualization, Simulation as a Service (SaaS)	Execution: Parallel/Distributed, Web-based					

… unfortunately / luckily a non exhaustive list

Both „Humans“ AND „Technology“ ar a Factor

- The term sociotechnical system was primarily introduced in the coal mine industry in the early 50’s to describe the **basic work systems**. Over time, this principle was expanded to whole organizations and an even more macroscopic domains such as communities and entire industrial sectors
- A sociotechnical system is **set of technical and social subsystems** that are structured in a certain way and tries to achieve a predefined primary function.
- In addition, various secondary functions arise directly or indirectly by the **interaction between subsystems** and are often related to the fulfilment of the primary function.

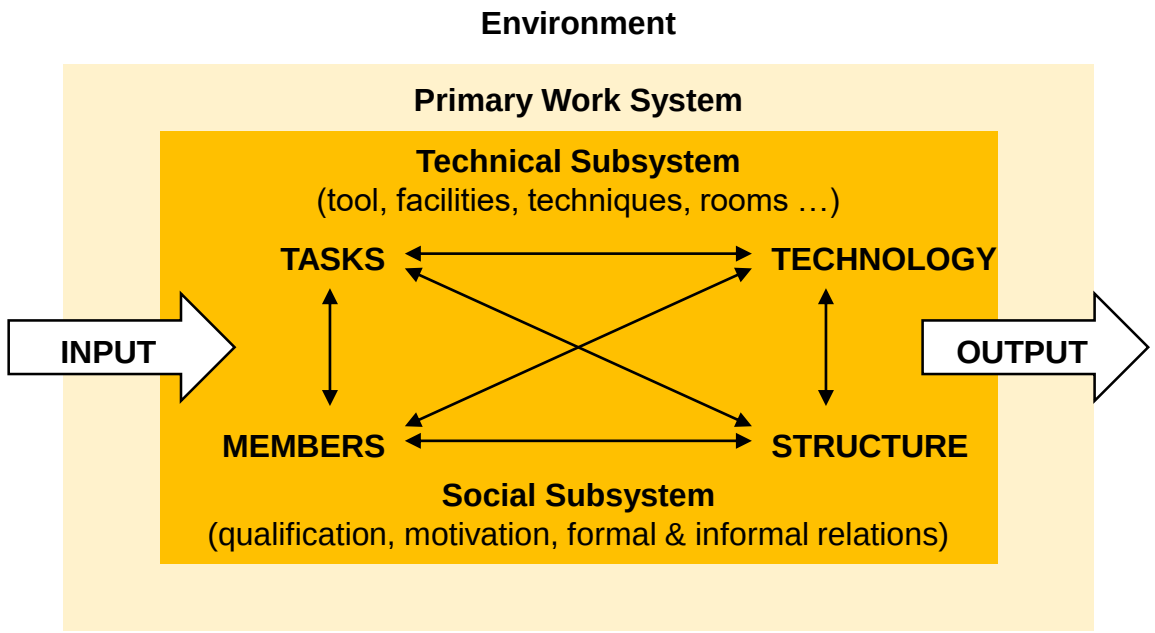


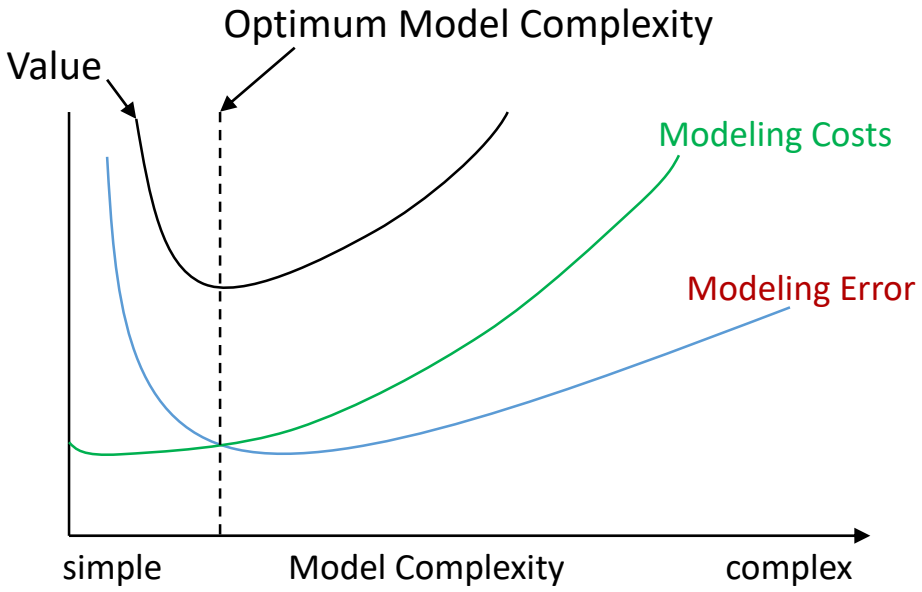
Illustration translated from: Sydow, J., 1985. *Der soziotechnische Ansatz der Arbeits- und Organisationsgestaltung : Darstellung, Kritik, Weiterentwicklung*, Frankfurt/Main [u.a.]: , Campus-Verlag.

Model Tradeoff

Finding the optimal model complexity might be one of the biggest challenges in modeling and simulation studies!

(A perfect model one year late is useless!)

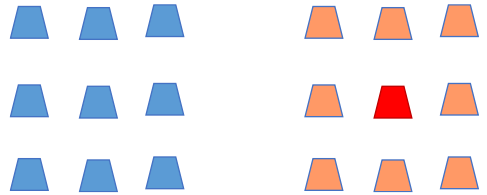
> *"Things should be made as simple as possible, but not any simpler"* - Albert Einstein



Systemic Risks – where do they come from ? (1/2)

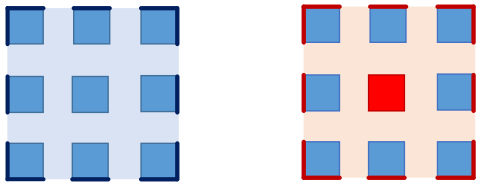
Homogeneity - Monoculture

- Missing Diversity – one fails – all fail



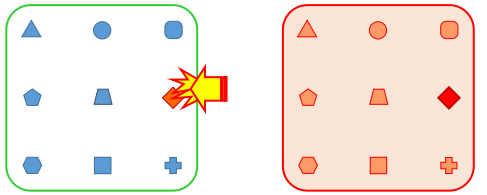
Interdependency

- Heavily interdependent systems: attack one, everything fails



Connectedness

- Attack one, attack all



Physical Effects

- Remote Controlled Attacks, Drones, Bombs
- Car-Hacking, -Deactivating, Crashing

Systemic Risks – where do they come from ? (2/2)

Technical Complexity

- Large Scale IOT
- The curse of “Artificial” Intelligence

Interaction with human individuals

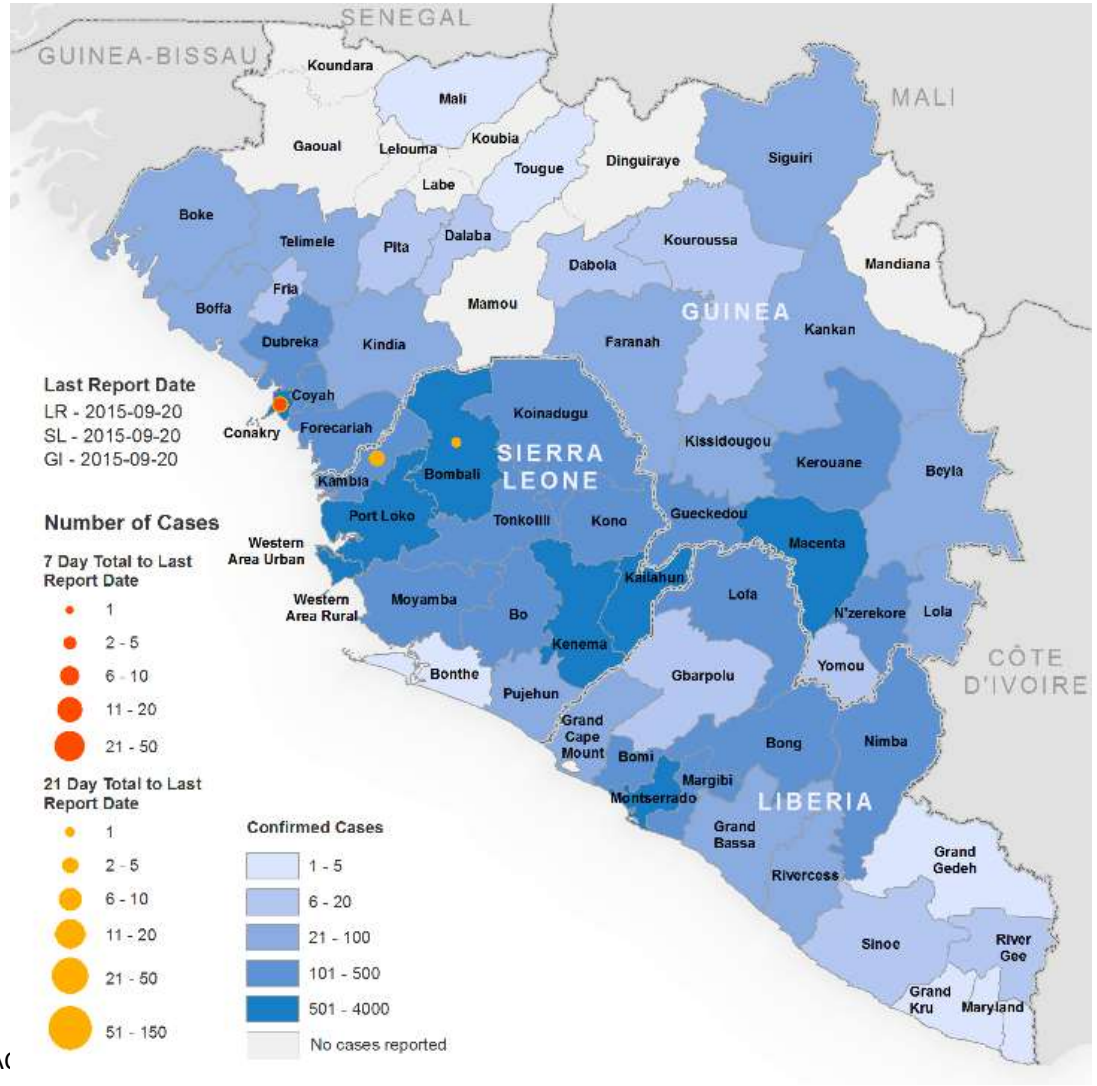
- Human machine Interface issues,
  Emotional decision making,
  Human complexity, ...

Interactions with crowds / societies

- Emergent behavior, panic, ...

Example – Modeling the Ebola Outbreak 2014/15*

- The outbreak in West Africa, (first cases notified in March 2014), was the largest and most complex Ebola outbreak since the Ebola virus was first discovered in 1976.
- The average Ebola virus disease case fatality rate was around 50%.
- Ebola spreads through human-to-human transmission via direct contact with blood, secretions, organs or other bodily fluids of infected people, and with surfaces and materials contaminated with these fluids.

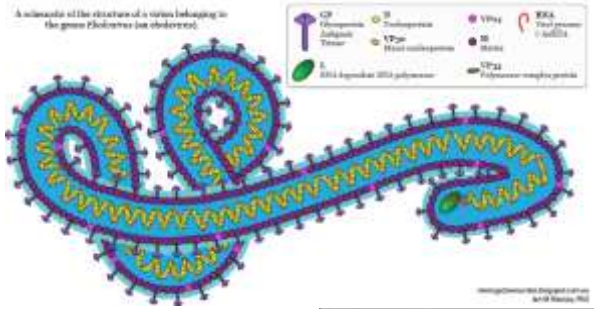


Source: WHO (http://who.int/ accessed Oct. 9th 2015)

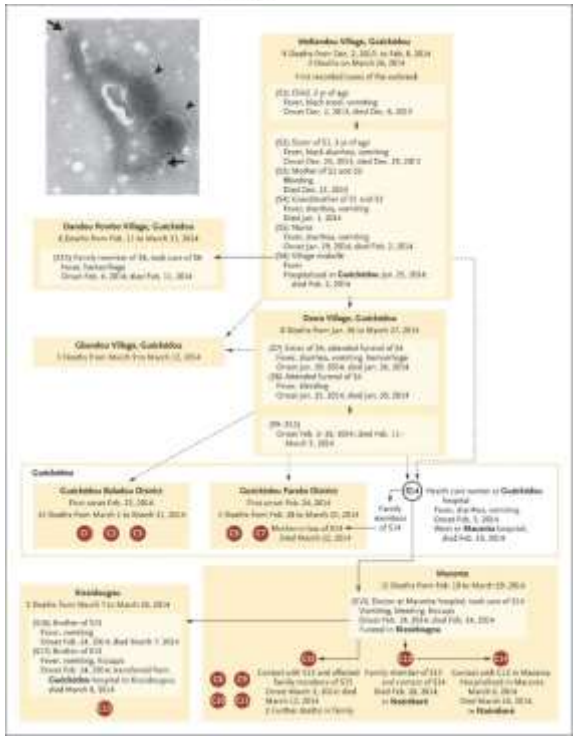
*) 29th European Simulation and Modelling Conference 2015, AN AGENT-BASED APPROA(
Dietmar Neubacher, Nikolaus Furian, Siegfried Vössner

What is the right Level of Detail?

Biochemical level:

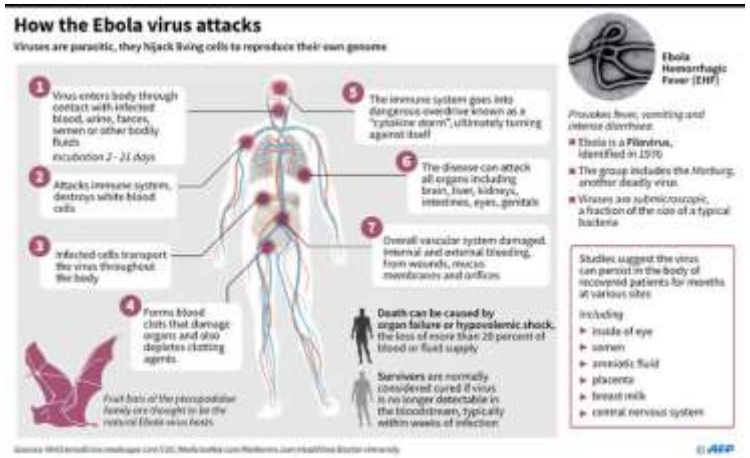


Social interaction* / network level:



*) Emergence of Zaire Ebola Virus Disease in Guinea, New England Journal of Medicine, 2014; 371:1418-1425October 9, 2014

Individual level:



Population level

N: number of individuals in the population

S: number of *Susceptible* individuals
I: number of *Infective* individuals
R: number of *Removed* (recovered/dead) individuals

$$S + I + R = N$$

homogeneous mixing:

$$\frac{dS(t)}{dt} = -\beta S \frac{I}{N}$$

$$\frac{dI(t)}{dt} = \beta S \frac{I}{N} - \mu I$$

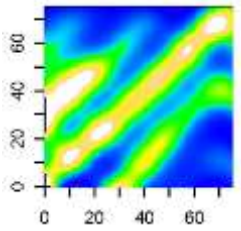
$$\frac{dR(t)}{dt} = \mu I$$

$S \to I$ with rate β (infection rate)
$I \to R$ with rate μ (recovery rate)

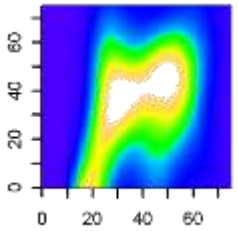
Spread of Disease and Contact Patterns

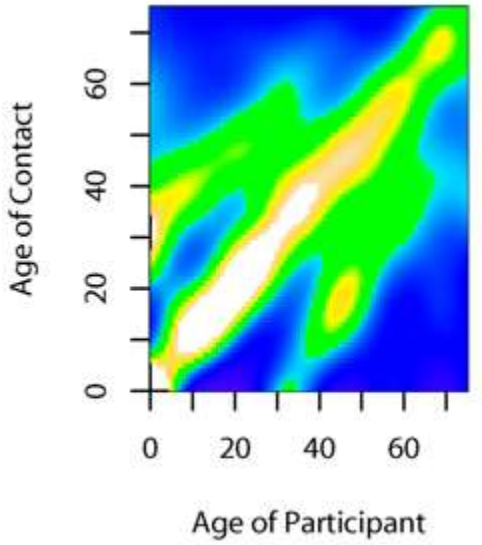
- People tend to have close contacts to specific age groups, primarily depending on their age.
- Age-related mixing also depends on the occasion of contacts.

Home



Work





Smoothed Contact Matrices
based on all reported Contacts
(Illustrated Country: Germany)

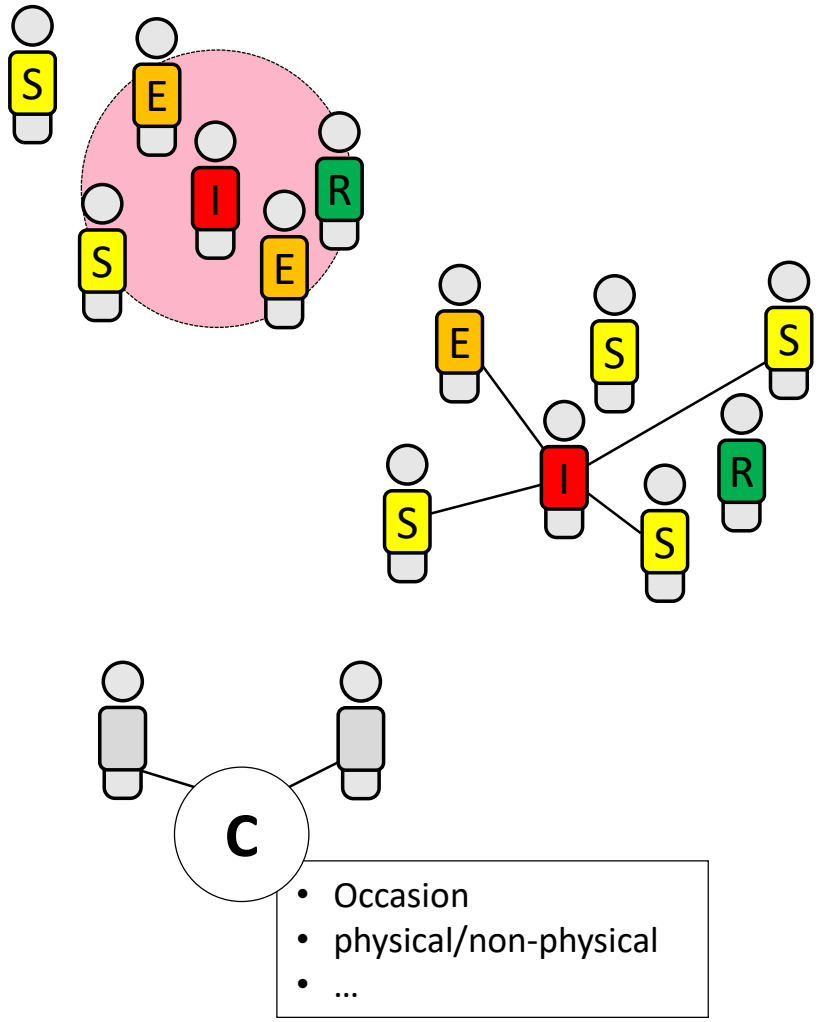
How does age-related contact patterns effect epidemic spread?

Picture Source: Mossong J et al. (2008) Social Contacts and Mixing Patterns Relevant to the Spread of Infectious Diseases. PLoS Med 5(3):

Interaction of individuals in AB-Simulations

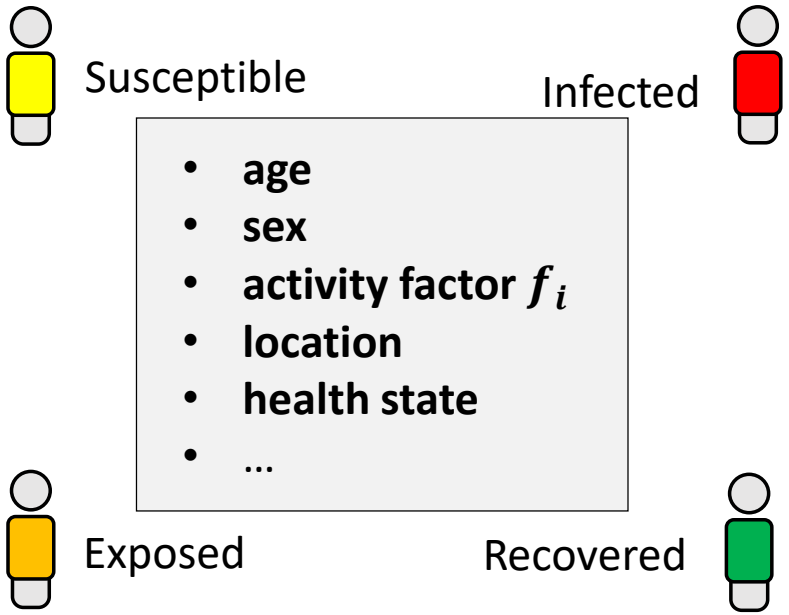
- **Common approaches**
- Interactions are based on local proximity, or explicitly defined networks.

- **Proposed approach**
- Focus on the contact, participating agents and type of contacts.



Health States: S…Susceptible; E…Exposed; I…Infected; R…Recovered

Modeling a Population

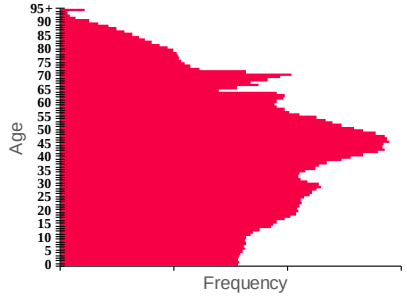


Every agent is assigned a health state, which might change over time.

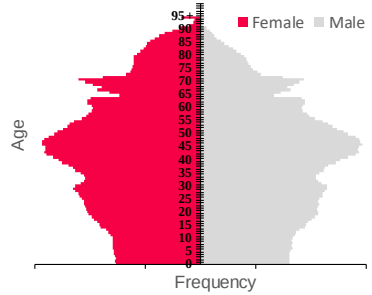
Individual behavior

In our approach the behavioral reaction to a disease is only related to the agents health state, as exposed or infected agents reduce their activity factor.

Real demographic data* is used to generate a realistic age-distributed population.



This data* is also used to generate a realistic gender-distribution.



Healthy agents try to achieve a specific amount of daily contacts dc^*.

Age-set	Mean Number of daily contacts	(Standard Deviation)
0-4	10,21	7,65
5-9	14,81	10,09
10-14	18,22	12,27
15-19	17,58	12,03
20-29	13,57	10,6
30-39	14,14	10,15
40-49	13,83	10,86
50-59	12,3	10,23
60-69	9,21	7,96
70+	6,89	5,83

The agents are placed in a 2D continuous environment, according to defined density maps

homogeneous

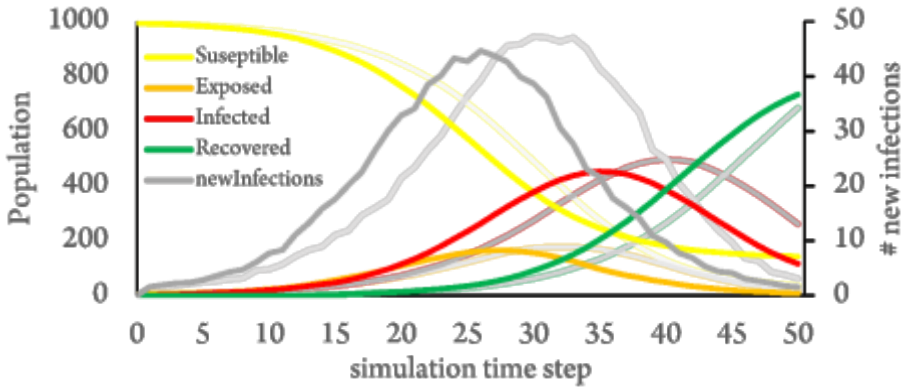
heterogeneous/ continuous

heterogeneous/ discrete

Spread depends heavily on Contact Pattern Assumptions

Behavior of the system* as contact probabilities are based on:

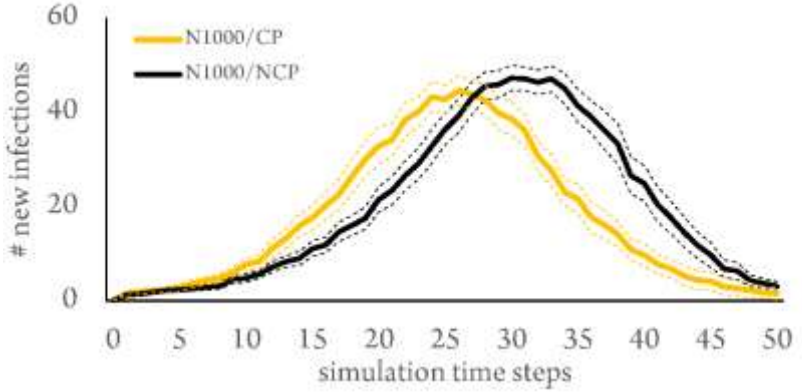
- Distance between agents
- Age-related contact patterns



Age-related contact patterns accelerate epidemic outbreaks.

The disease spreads faster and wider, especially through high risk age-sets.

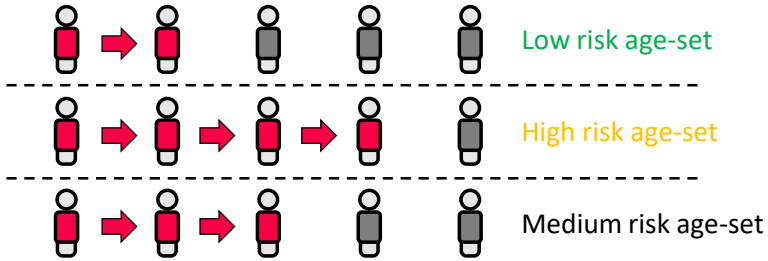
Daily infections using contact patterns (CP) and without (NCP)



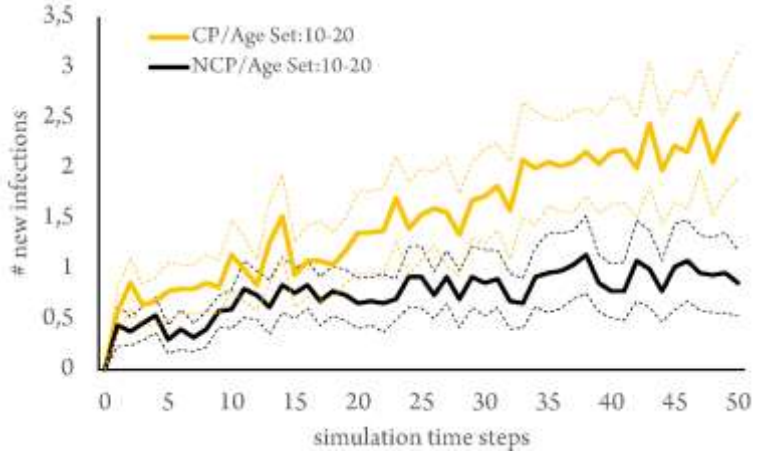
* Each scenario was simulated n=50 times with a population of 1000 individuals. (dotted lines indicate 95% Confidence Interval)

Underestimating risk in common approaches

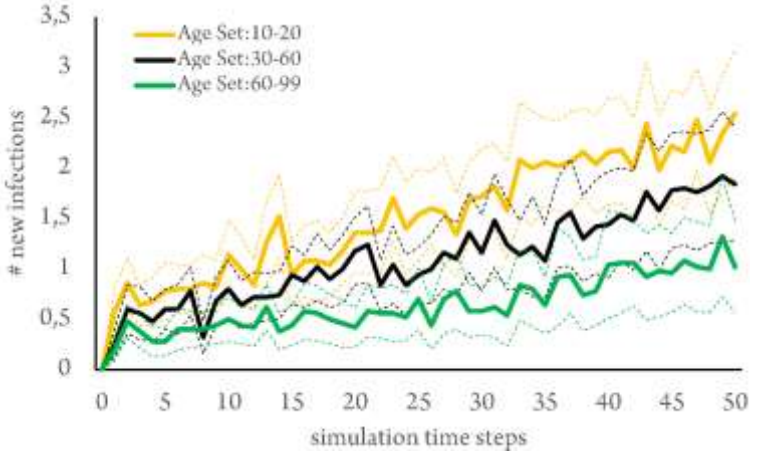
- Significant influence of the initial infected age-set.
- Existence of high-risk age-groups that spread the disease much faster.



Simulated daily infections using age-related contact patterns (CP) and not using them (NCP)



Simulated daily infections over various initially infected age-sets



* Each scenario was simulated n=50 times with a population of 1000 individuals. (dotted lines indicate 95% Confidence Interval)

Danke für Ihre Aufmerksamkeit

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KONTAKT:

Univ. Prof. DI. Dr. Siegfried Vössner

Technische Universität Graz

Kopernikusgasse 24, A-8010 Graz

Tel.: +43 316 873-8001

voessner@tugraz.at , www.tugraz.at