# Machine Learning in Crowd Modeling & Simulation
# Lecture 2 - simulation software

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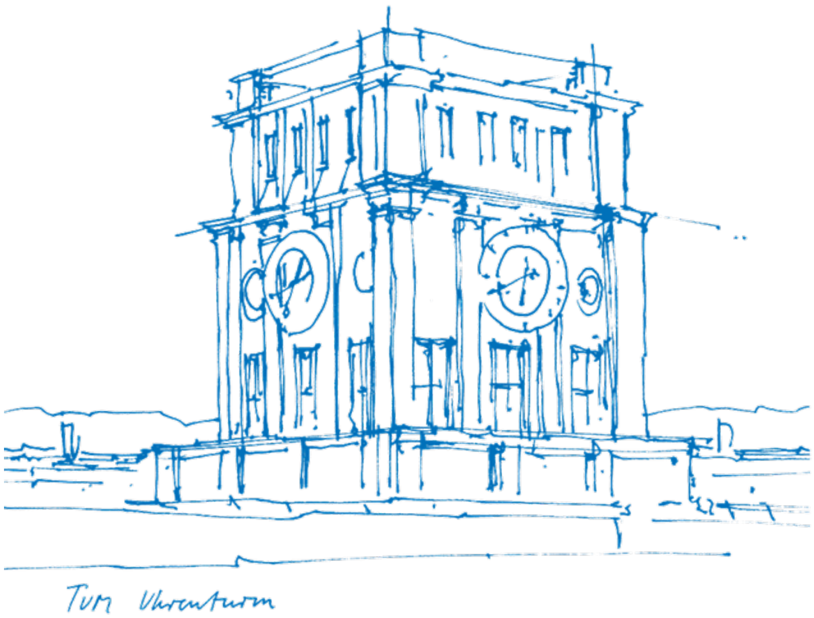
This video: short introduction to SIR models



# Models for infections

## General problem

Study the spread of an infection inside a population
[Boccara, 2010, Boccara et al., 1993, Kermack and McKendrick, 1927].

## Specific problem

Study the spread of an infection inside an enclosed area (using Vadere!). This is important to determine the parameters of the general model.

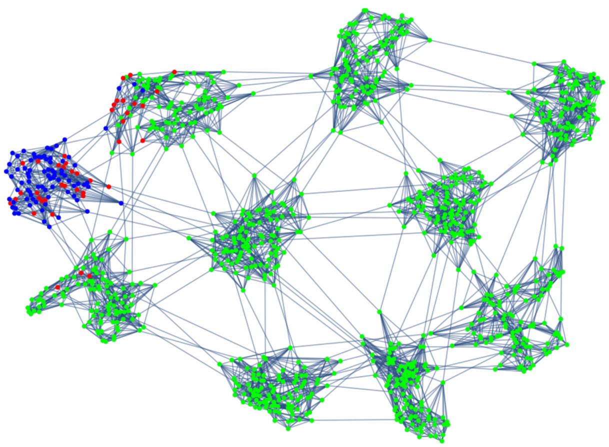


Figure: General problem modeled with a social graph [1].
[1] https://community.wolfram.com/groups/-/m/t/1907703

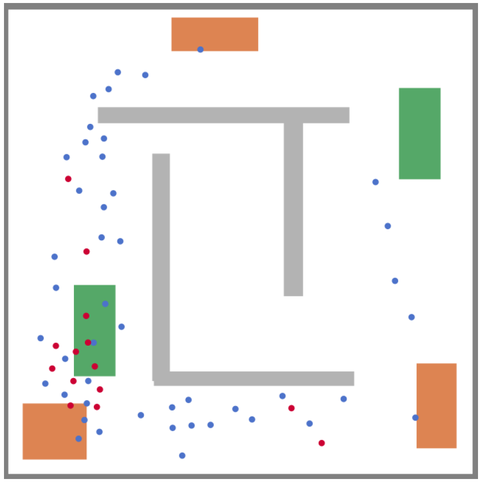


Figure: Specific problem modeled in Vadere.

# SIR models

## Differential equation based: Kermack–McKendrick epidemic model

From [Boccara, 2010]: To [study] the spread of an infection within a population, [Kermack and McKendrick, 1927] divide the population into three disjoint groups.

1. **(S)usceptible** individuals are capable of contracting the disease and becoming infective.
2. **(I)nfective** individuals are capable of transmitting the disease to others.
3. **(R)emoved** individuals have had the disease and are dead, or have recovered and are permanently immune, or are isolated until recovery and permanent immunity occur.

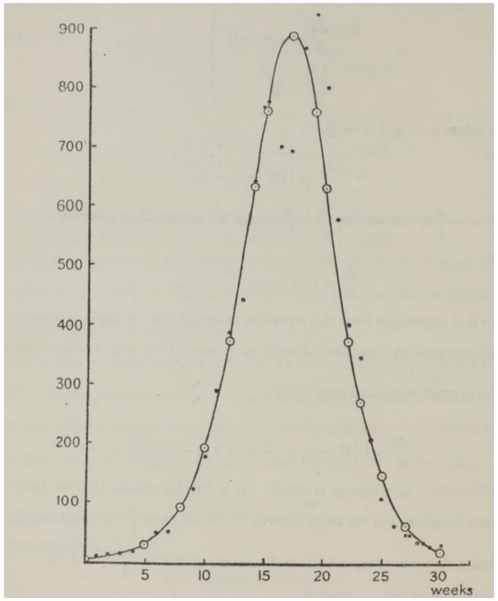



Figure: From [Kermack and McKendrick, 1927]: The chart is based on number of deaths (number of "removed") from a plague in the island of Bombay over the period December 17, 1905, to July 21, 1906. The ordinate represents the number of deaths per week, and the abscissa denotes the time in weeks.

# SIR models

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3. **(R)emoved** individuals have had the disease and are dead, or have recovered and are permanently immune, or are isolated until recovery and permanent immunity occur.

Infection and removal are governed by the following rules:

$$\frac{d}{dt}S = -pSI, \quad \frac{d}{dt}I = pSI - rI, \quad \frac{d}{dt}R = rI.$$

Here, $p$ is the infection rate, and $r$ is the removal rate.

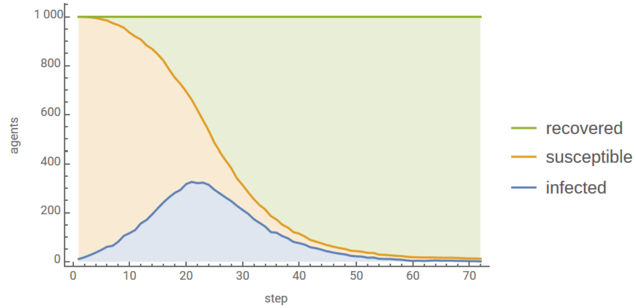


Figure: Visualization of an “outbreak” over time, which is similar to what the ODE model will show. From: [1]

[1] https://community.wolfram.com/groups/-/m/t/1907703

# SIR models

## General definition

Modeling (S)usceptible, (I)nfected, (R)emoved [Boccara, 2010] with several implementations:

1. Differential equation (with $p$ the infection rate, and $r$ the removal rate)

$$\frac{d}{dt}S = -pSI, \; \frac{d}{dt}I = pSI - rI, \; \frac{d}{dt}R = rI.$$

2. Graphs (see for example [1], also includes cellular automata)
3. Agent based models (overlap with graphs, but can be localized) [2]

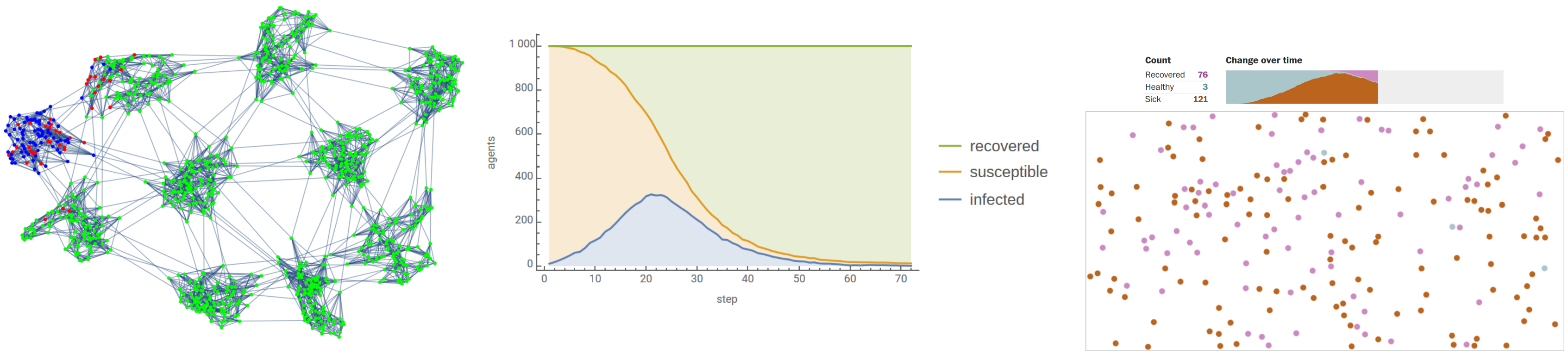


Figure: Social interactions graph from [1], with visualization of the “outbreak” over time (center). The right panel shows an agent based simulation from [2].

[1] https://community.wolfram.com/groups/-/m/t/1907703
[2] https://www.washingtonpost.com/graphics/2020/world/corona-simulator/

# SIR model in Vadere

## How can we determine if social distancing is reasonable?

Rules for Vadere SIR model:

1. At the beginning of the simulation, there are $S$ susceptible and $I$ infective.
2. At every time step, the neighborhood ($1m$ radius) of every pedestrian is checked for infective neighbors. With probability $p$ per infective neighbor, the given pedestrian also turns infective.
3. The distance that pedestrians keep to others is determined by the cost function around each one of them. In the Optimal Steps Model, this is the parameter `AttributesPotentialCompactSoftshell:pedPotentialPersonalSpaceWidth`.

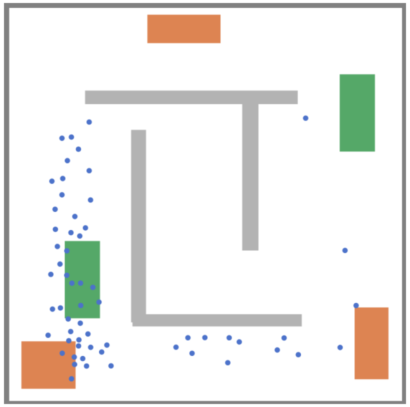

Figure: Social distancing "off": `pedPotentialPersonalSpaceWidth=0.5`

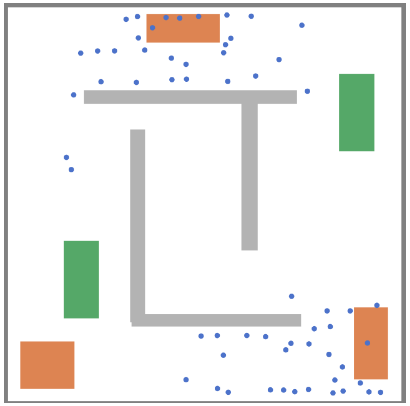

Figure: Social distancing "on": `pedPotentialPersonalSpaceWidth=5.2`

# SIR model in Vadere

## A possible implementation

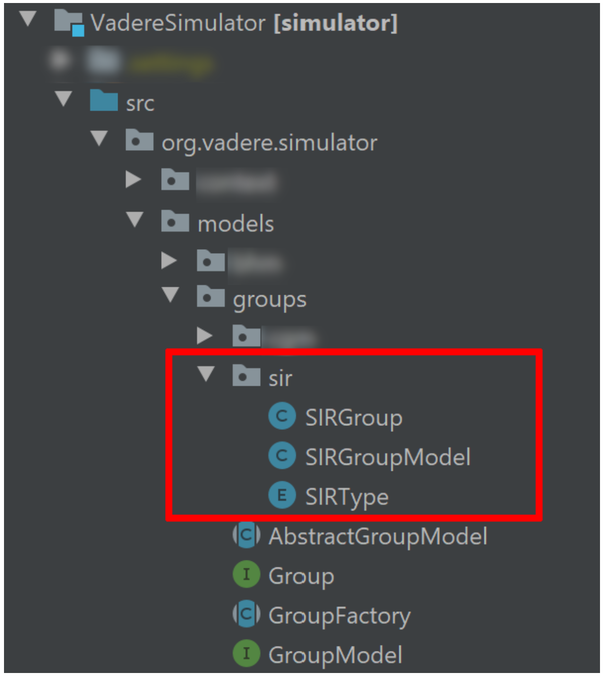


Figure: The submodel `SIRGroupModel` in the package hierarchy of `VadereSimulator`.

- `SIRGroupModel` is part of `org.vadere.simulator.models.groups.sir`
- The `SIRGroupModel` implements `AbstractGroupModel<SIRGroup>`
- This makes it a sub-model, i.e. it can be used by main models (e.g. OSM, GNM, ...) through the GUI.
- The attributes of the `SIRGroupModel` are defined in `AttributesSIRG` in the `VadereState` package `org.vadere.state.attributes.models`:
  - `int infectionsAtStart = 0`
  - `double infectionRate = 0.01`
  - `double infectionMaxDistance = 1`

# SIR model in Vadere

## Visualization of the results

The `SIRGroupModel` in action:

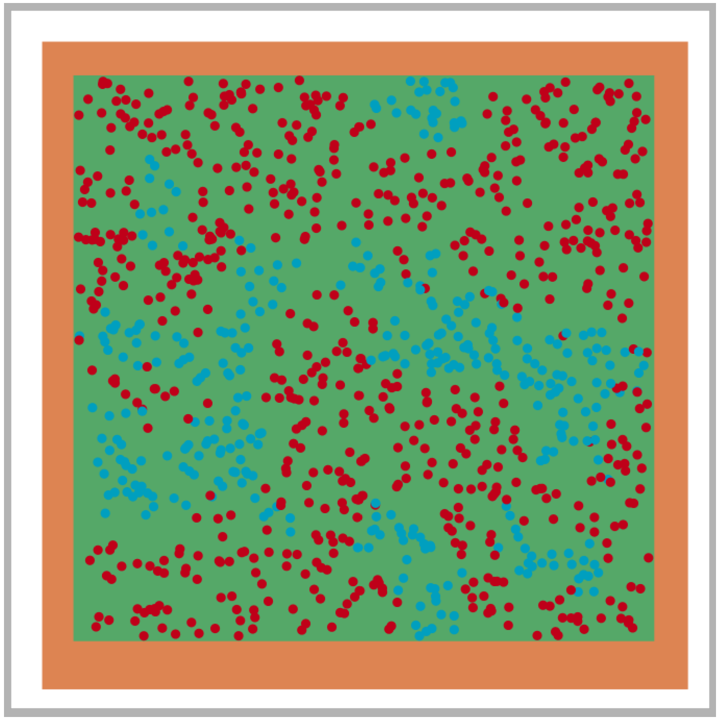

Figure: Visualization of the SIR model in Vadere, with 1000 static pedestrians.

# SIR model in Vadere

## Visualization of the results

Plotly/Dash visualization tool for the Vadere results:

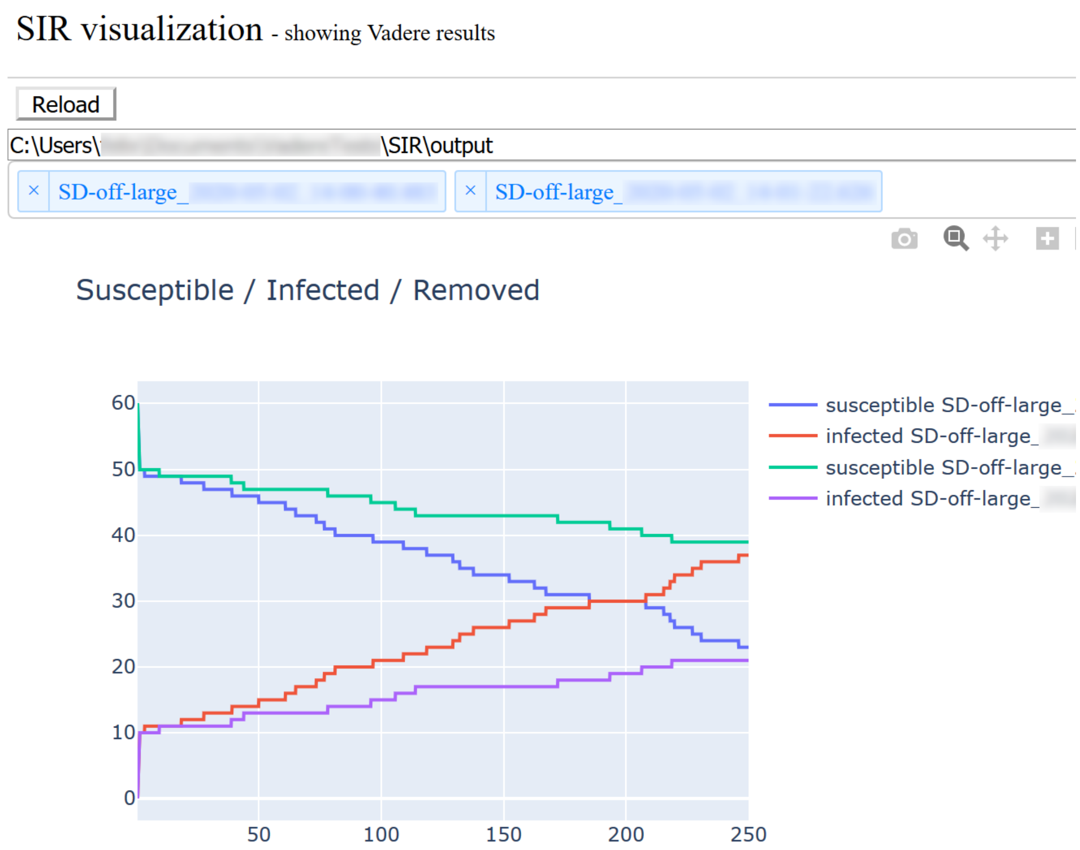


Figure: Visualization of the SIR results from two Vadere runs, comparing social distancing “on” and “off”.

# SIR model in Vadere

## Things to be aware of

The SIR model in Vadere is more complicated than the graph based model from Wolframalpha: essentially, it is an agent based model operating on a time-dependent neighborhood graph. However:

1. More complicated models are not always better models (in fact, usually the opposite is true—see “Occam’s razor”).
2. Reality is always more complicated than models (noise, time delays, time-dependent effects, ...)
3. Using models for predictions about reality is dangerous (but often the only possibility we have).
4. You should not blindly trust models, and **always validate against real data**.
5. The SIR model in Vadere I presented here is **entirely made up** and **not validated**. It only serves as an illustration of localized infection and spreading models.

# Literature I

Boccara, N. (2010).
*Modeling Complex Systems*.
Graduate Texts in Physics. Springer, New York, 2nd edition.

Boccara, N., Goles, E., Martinez, S., and Picco, P., editors (1993).
*Cellular Automata and Cooperative Systems*.
Springer Netherlands.

Kermack, W. O. and McKendrick, A. G. (1927).
A contribution to the mathematical theory of epidemics.
*Proceedings of the Royal Society of London. Series A, Containing Papers of a Mathematical and Physical Character*, 115(772):700–721.