A study on the effect of vaccination on an agent-based stochastic SIRS model

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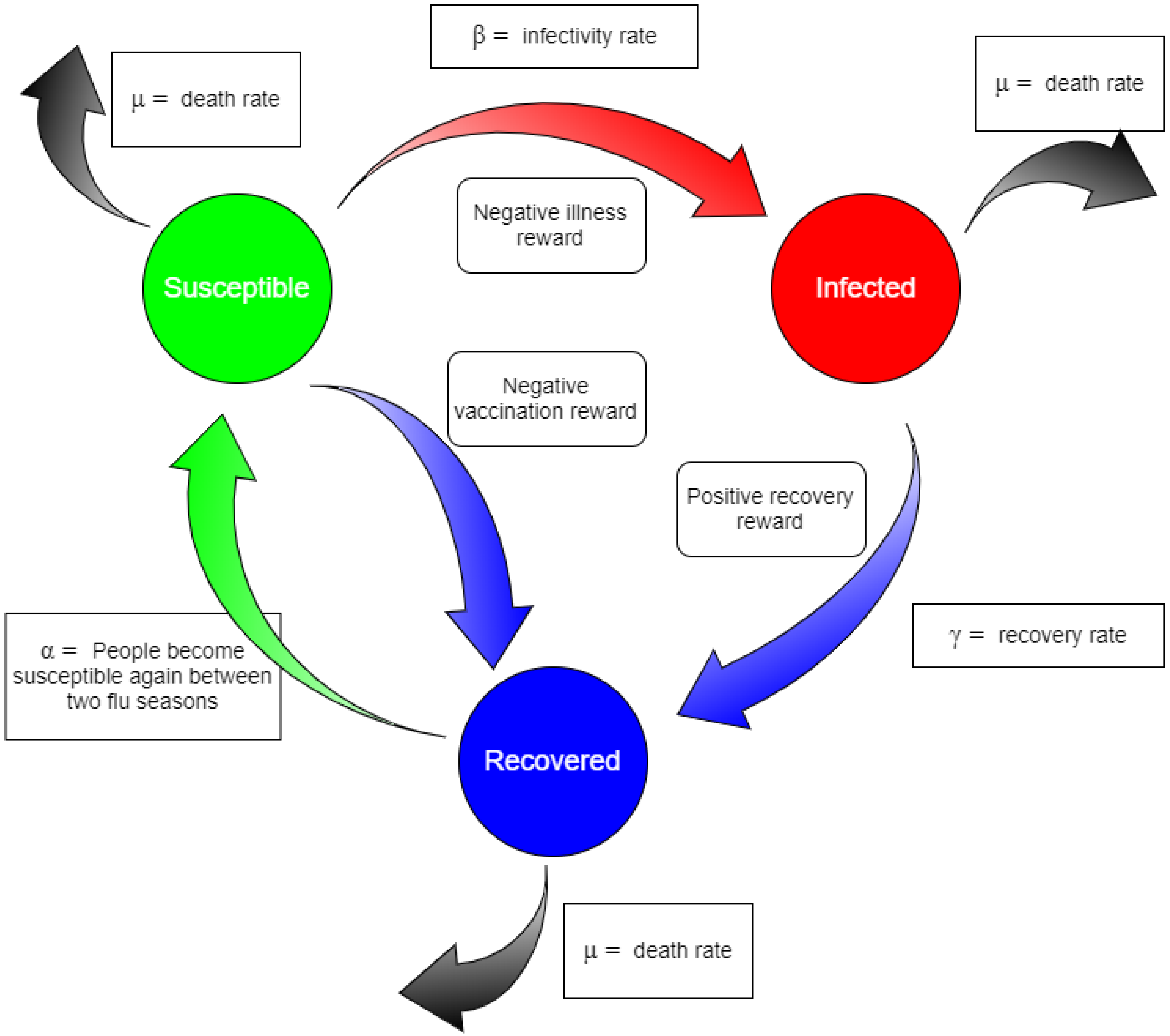
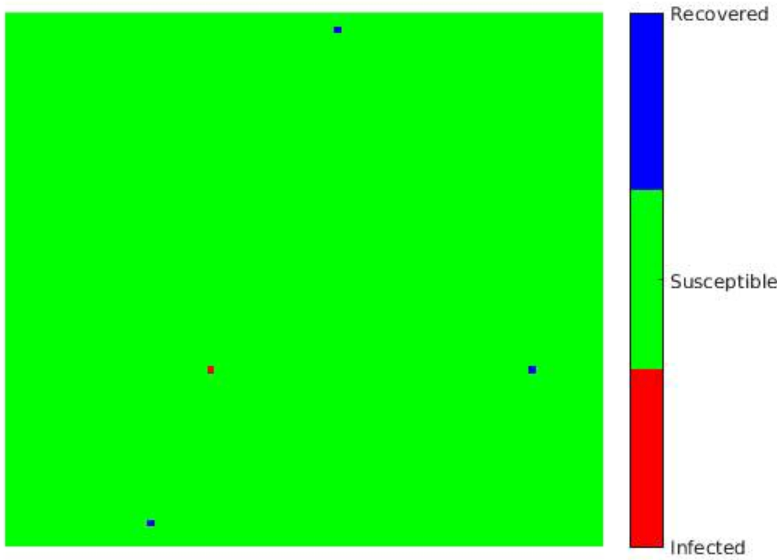
Influenza, MP - Fotolia, https://www.nfid.org/infectious-diseases/influenza-flu/

Model

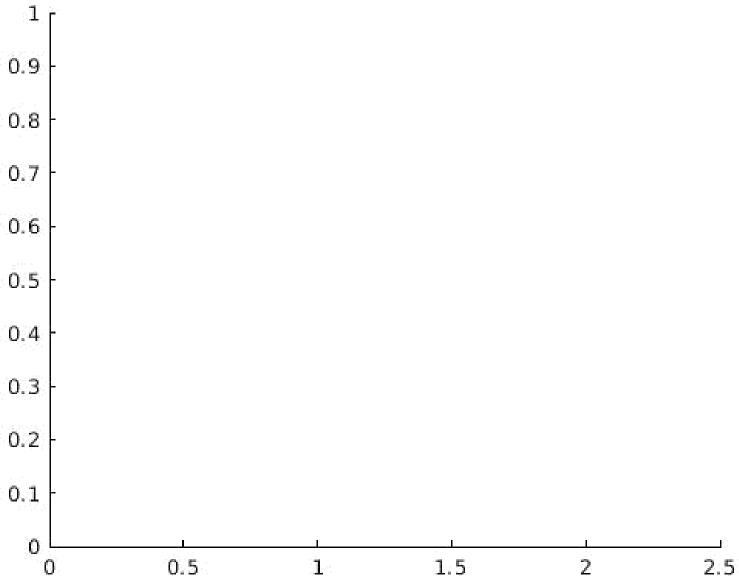
- Grid-like system
- 4 attributes per person:
  - Age
  - State (S, I, R)
  - Vaccination choice
  - Reward
- SIRS disease stochastic evolution
- Vaccination choice based on reward
- Optional displacement



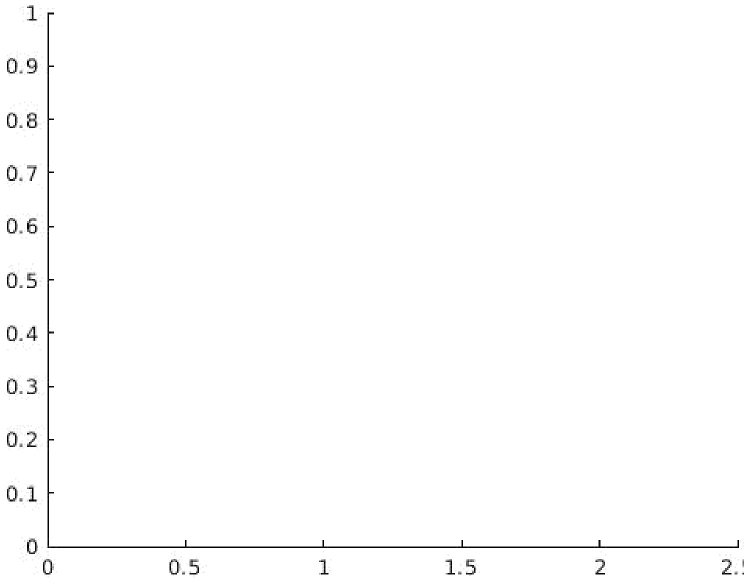
Example of the SIRS model with vaccination



Grid-like system showing the states of the agents



State density

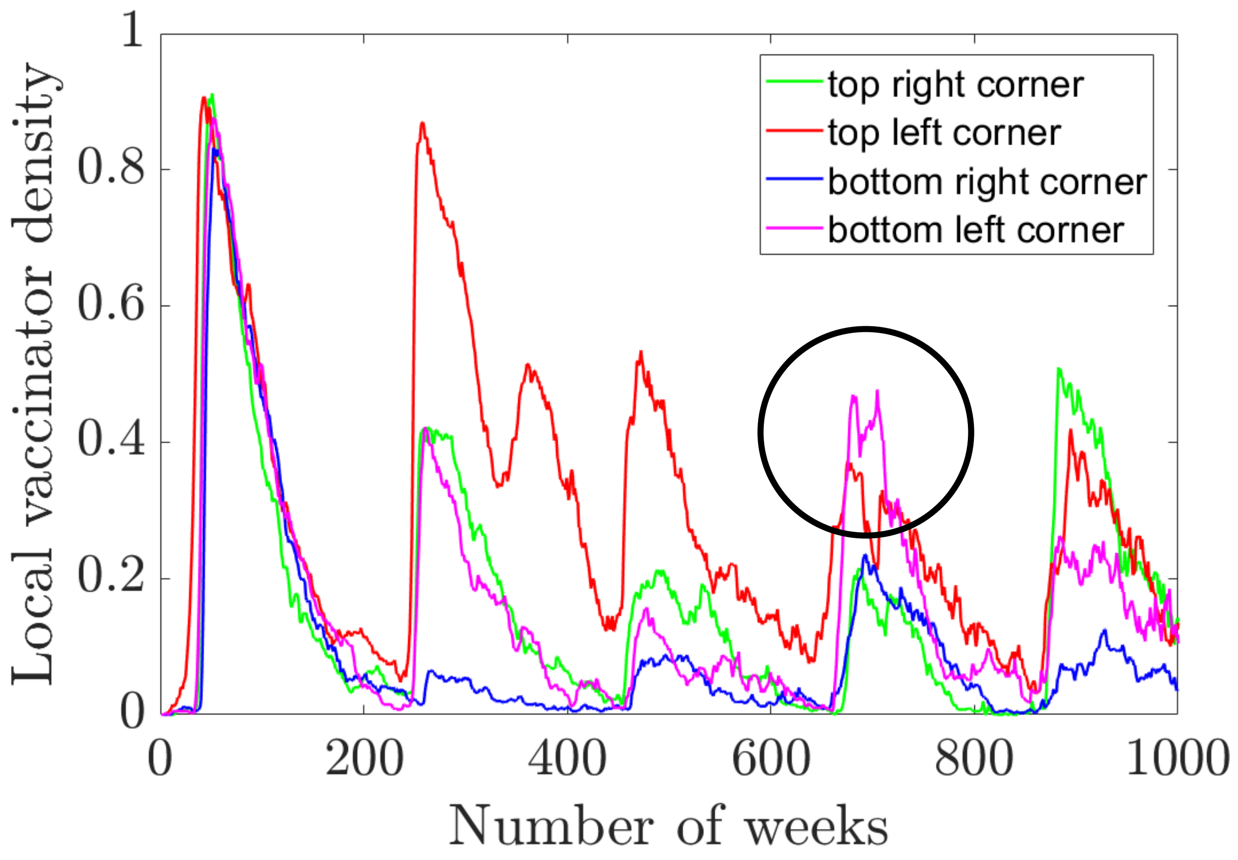


Vaccinator density

Shielding and herd immunity

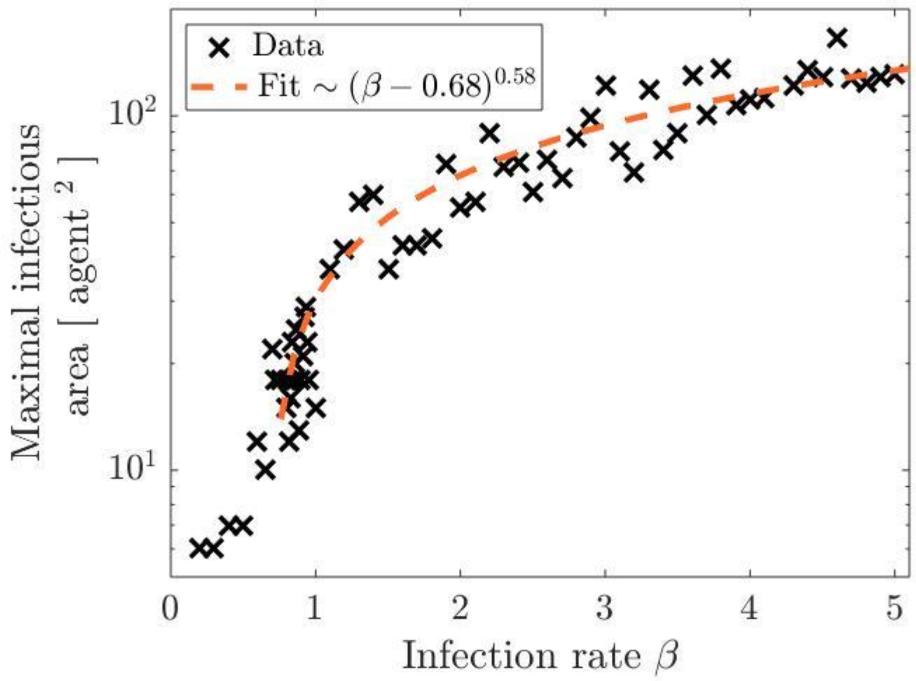
- Area around patient zero has higher density of vaccinators than other areas
- Other areas are shielded from the disease
- A new outbreak is triggered by the diminished vaccination rate of top left area
- In the case of a system wide outbreak, other areas can be more severely impacted than upper left area since the latter benefits from herd immunity

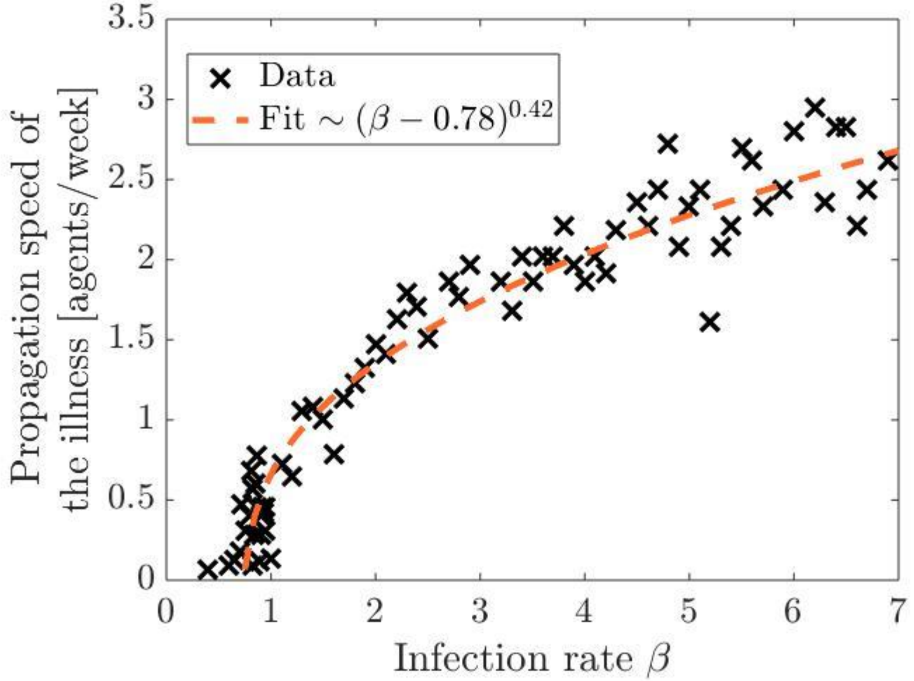
Local vaccination density for Patient Zero at fixed position in top left of grid



β variation and phase transition

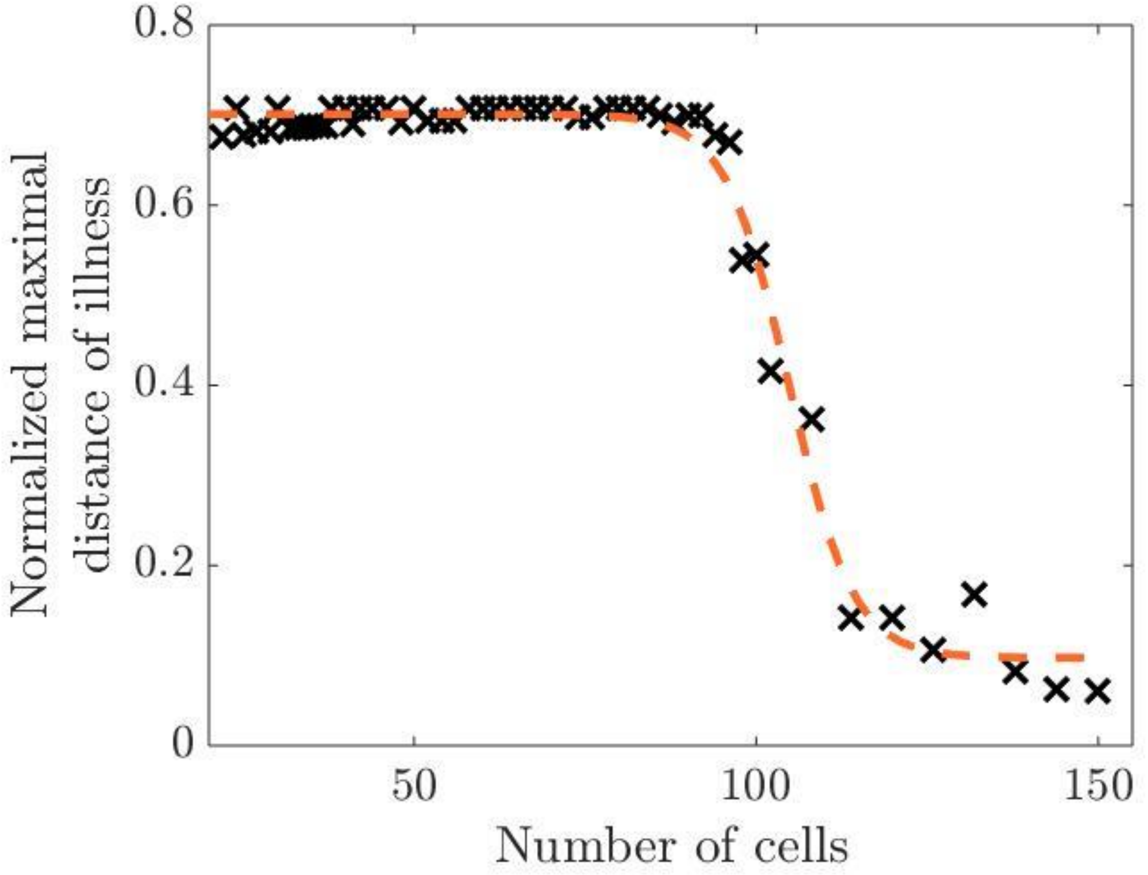
- As infection rate β increases, more people get infected faster
- We observe a phase transition at β = 1. This corresponds to the shift from a local disease to a global one
- A local disease is contained within one area of the total system
- A global disease spreads throughout the whole system





System size variation and phase transition

- For a small system the disease reaches the borders before the simulation ends
- For bigger systems the disease doesn't have time to reach the borders. So the maximal distance remains constant, whilst the normalization factor increases
- We observe the opposite phase transition than before: as system size increases, disease goes from global to local (w.r.t. system size)



Conclusions

- Shielding and herd immunity
- Phase transition from local to global disease for increasing infection rate β
- Inverse phase transition for increasing system size

Elements of further research

- Study of topology of the system (varying the shape of the system or introducing obstacles)
- Study of system with agent displacement
- Complexifying the model (e.g. adding incubation time)

Thank you for your attention

Questions?

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